



Proceedings of the 50th Winter Simulation Conference

Victor Chan, Andrea d'Ambrogio, Grégory Zacharewicz, Navonil Mustafee

► To cite this version:

Victor Chan, Andrea d'Ambrogio, Grégory Zacharewicz, Navonil Mustafee (Dir.). Proceedings of the 50th Winter Simulation Conference: WSC Turns 50: Simulation Everywhere!., 2017. hal-01858088

HAL Id: hal-01858088

<https://hal.science/hal-01858088>

Submitted on 2 Jan 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/327130062>

Proceedings of the 50th Winter Simulation Conference : WSC Turns 50: Simulation Everywhere!

Book · December 2017

CITATIONS

0

READS

2

4 authors, including:



Andrea D'Ambrogio

University of Rome Tor Vergata

135 PUBLICATIONS 905 CITATIONS

[SEE PROFILE](#)



Gregory Zacharewicz

IMT École des Mines d'Alès

143 PUBLICATIONS 604 CITATIONS

[SEE PROFILE](#)



Navonil Mustafee

University of Exeter

102 PUBLICATIONS 1,070 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



Enterprise Operating System (EOS) [View project](#)



Multi Agent/HLA Enterprise Interoperability [View project](#)

WSC^{turns} 50

SIMULATION
EVERYWHERE



CONFERENCE COMMITTEE

General Chair

Ernest H. Page,
MITRE

Program Chair

Gabriel Wainer,
Carleton University

Business Chair

John A. Tufarolo,
MITRE

Proceedings Editors

Victor Chan,
Rensselaer Polytechnic Institute

Andrea D'Ambrogio,
University of Rome Tor Vergata

Gregory Zacharewicz,
University of Bordeaux

Navonil Mustafee,
University of Exeter

Sponsorship Chair

Rene Reiter,
AnyLogic

Exhibit/Vendor Chairs

Jayne Talbot,
Raytheon

Renée Thiesing,
SIMIO LLC

Registration Chairs

John Fowler,
Arizona State University

Alice E. Smith,
Auburn University

Publicity Chairs

Christine Harvey,
MITRE

Rodrigo Castro,
University of Buenos Aires

Yunbok Kim,
Sung Kyun Kwan University

Steffen Strassburger,
TU Illmenau

WSC Board Liaison

David Nicol,
University of Illinois at Urbana-Champaign



2017 Winter Simulation Conference

***WSC Turns 50:
Simulation Everywhere!***

Final Program Exhibit Directory

**December 3-6, 2017
Red Rock Casino Resort & Spa
Las Vegas, NV**

Table of Contents

WSC '17 Committee	Inside front cover
Program Highlights	2
Program & Events Schedule	3
Sunday Vendor Workshops	5
Special Events.....	6
Sponsors	7
Preface.....	9
Tribute to Julian Reitman	12
Keynote	14
Titans of Simulation	15
Military Keynote.....	17
History of Simulation Keynote	18
MASM Conference Keynote	19
Vendor Track.....	20
Final Program Abstracts	24
Sunday: PhD Student Colloquium, Poster Session	24
Monday Abstracts, Poster Session	38
Tuesday Abstracts	75
Wednesday Abstracts	126
Exhibitor Directory.....	147
Exhibit Hall Floor Plan.....	152
WSC '17 Track Coordinators	153
WSC '17 Referees	156
WSC Board of Directors	162
WSC '18 Announcement	163
WSC Foundation	165
WSC Proceedings Instructions	167
Future WSC Conferences & Sponsoring Societies	Back cover



Program Highlights

Welcome to WSC 2017

Ernest H. Page, WSC 2017 General Chair

Monday, December 4, 8:00am-8:30am, Summerlin Ballroom BCDE

50th Anniversary Keynote

Barry L. Nelson, Northwestern University

WSC 2067: What are the Chances?

Monday, December 4, 8:30am-9:30am, Summerlin Ballroom BCDE

Titans of Simulation

Bernard P. Zeigler, University of Arizona

Why Should We Develop Simulation Models in Pairs?

Monday, December 4, 12:20pm-1:20pm, Summerlin Ballroom BCDE

Robert G. Sargent, Syracuse University

A Perspective of Fifty-Five Years of the Evolution of Scientific Respect for Simulation

Tuesday, December 4, 12:20pm-1:20pm, Summerlin Ballroom BCDE

Military Keynote

Douglas D. Hodson, Air Force Institute of Technology (AFIT)

Military Simulation: A Ubiquitous Future

Monday, December 4, 10:00am-11:30am, Charleston A

History of Simulation Keynote

Brian W. Hollocks, Bournemouth University

History of Simulation in the United Kingdom

Monday, December 4, 1:30pm-2:30pm, Trails

MASM Keynote

Stéphane Dauzère-Pérès, Ecole des Mines de Saint-Etienne

Achievements and Lessons Learned from a Long-term Academic-Industrial Collaboration

Tuesday, December 5, 3:30pm-5:00pm, Veranda E

Poster Briefings, PhD Colloquium & General Poster Session

PhD Colloquium Presentations, 1:00pm-5:30pm, Trails

Poster Briefings, 3:30pm-5:20pm, Pavilion

PhD Colloquium & General Poster Session, 5:30pm-7:00pm*, Red Rock Ballroom Foyer

*Posters will be moved into the Red Rock Ballroom in the back of the exhibit area from Monday –Wednesday.

Vendor Workshops - Sunday

Free, in-depth workshops from leading simulation vendors. See page 5 for details.

Vendor Track Sessions – Monday & Tuesday

Exhibiting companies will present software tutorials, case studies, customer testimonials and introductory training sessions in these tracks, part of the regular technical program.

Program & Events Schedule

See hotel map (separate handout) for room locations.

Sunday, December 3

8:00am-6:00pm	Registration	Registration Desk
8:30am-12:00pm	Data Farming 101 Workshop	Hills
10:00am-12:00pm	Vendor Workshops	
	MathWorks	Veranda B
	Rockwell Automation (Arena® Simulation Software)	Veranda A
12:00pm-1:00pm	PhD Colloquium Lunch (invite only)	Veranda
PhD Colloquium		
1:00pm-2:00pm	Plenary	Trails
2:15pm-3:45pm	Session 1	Trails
3:45pm-4:00pm	PhD Colloquium	
	Refreshment Break	Trails Foyer
4:00pm-5:30pm	Session 2	Trails
5:30pm-7:00pm	PhD Colloquium	
	Poster Session	Red Rock Ballroom Foyer
12:30pm-2:30pm	Vendor Workshops	
	AnyLogic	Veranda C
	Applied Materials	Veranda B
	FlexSim Software	Veranda A
	Products, Inc.	Veranda A
	Simio Simulation & Scheduling Software	Veranda E
1:00pm-7:00pm	Simulation 101 Workshop	Hills
3:00pm-5:00pm	Vendor Workshops	
	AnyLogic	Veranda C
	CSPI	Veranda D
	Frontline Systems, Inc.	Veranda B
	LLamasoft	Veranda A
	Simio Simulation & Scheduling Software	Veranda E
3:30pm-5:20pm	Poster Briefings	Pavilion
5:30pm-7:00pm	Poster Session	Red Rock Foyer
6:00pm-8:00pm	I-SIM Council Meeting	Veranda C
6:30pm-7:00pm	TOMACS Editorial Board	Veranda D
6:30pm-7:00pm	New Attendee Orientation	Pavilion

Monday, December 4

7:00am-5:00pm	Registration	Registration Desk
7:00am-8:00am	Speakers Breakfast	Veranda
8:00am-9:30am	Welcome & Keynote	Summerlin Ballroom BCDE
9:30am-5:30pm	Exhibits Open	Red Rock Ballroom ABCDEF
9:30am-10:00am	Refreshment Break	Red Rock Ballroom ABCDEF
10:00am-11:30am	Military Keynote: Hodson	Charleston A
10:00am-11:30am	Technical Sessions	See program
11:30am-12:15pm	Lunch on Your Own	
12:20pm-1:20pm	Titans: Bernie Zeigler	Summerlin Ballroom BCDE
1:30pm-2:30pm	History of Simulation Keynote: Hollocks	Trails
1:30pm-3:00pm	Technical Sessions	See program
3:00pm-3:30pm	Refreshment Break	Red Rock Ballroom ABCDEF
3:30pm-5:00pm	Technical Sessions	See program
5:30pm-8:30pm	Journal of Simulation Meeting	Veranda A
6:30pm-8:30pm	General Reception	Summerlin Ballroom BCDE

Tuesday, December 5

7:00am-5:00pm	Registration	Registration Desk
7:00am-8:00am	Speakers Breakfast	Veranda
8:00am-9:30am	Technical Sessions	See program
9:30am-5:30pm	Exhibits Open	Red Rock Ballroom ABCDEF
9:30am-10:00am	Refreshment Break	Red Rock Ballroom ABCDEF
10:00am-11:30am	Technical Sessions	See program
11:30am-12:15pm	Lunch on Your Own	
12:20pm-1:20pm	Titans: Bob Sargent	Summerlin Ballroom BCDE
1:30pm-3:00pm	Technical Sessions	See program
3:00pm-3:30pm	Refreshment Break	Red Rock Ballroom ABCDEF
3:30pm-5:00pm	Technical Sessions	See program
3:30pm-5:00pm	MASM Keynote: Dauzère-Pérès	Veranda E
5:30pm-6:30pm	ACM/SIGSIM Meeting	Veranda A
6:15pm-8:00pm	INFORMS-SIM Meeting	Trails
6:30pm-8:30pm	Vendor User Groups	See page 6
6:30pm-8:00pm	MASM Reception	Veranda E

Wednesday, December 6

7:00am-11:30am	Registration	Registration Desk
7:00am-8:00am	Speakers Breakfast	Veranda
8:00am-9:30am	Technical Sessions	See program
9:00am-11:30am	Exhibits Open	Red Rock Ballroom ABCDEF
9:30am-10:00am	Refreshment Break	Red Rock Ballroom ABCDEF
10:00am-11:30am	Technical Sessions	See program

Sunday Vendor Workshops

anyLogistix

12:30pm-2:30pm/Veranda C

anyLogistix: How to Enhance Supply Chain Analysis

AnyLogic

3:00pm-5:00pm/Veranda C

Anylogic: Simulation Modeling is Migrating to the Cloud

Applied Materials

12:30pm-2:30pm/Veranda B

AUTOMOD® & AUTOSCHED®: Performance, Scalability and Accuracy

CSPI

3:00pm-5:00pm/Veranda D

ezDFS (Dispatching, Forecasting, and Scheduling Solution)

Flexsim Software Products, Inc.

12:30pm-2:30pm/Veranda A

Hands-on Optimization of Healthcare Systems

Frontline Systems, Inc.

3:00pm-5:00pm/Veranda B

Full-Spectrum Analytics in Excel, Tableau, Power BI, or Your Own Application

LLamasoft, Inc.

3:00pm-5:00pm/Veranda A

Simulating Supply Chains with Supply Chain Guru

MathWorks

10:00am-12:00pm/Veranda B

How to Simulate, Analyze, and Optimize Operations Research with MATLAB

Simio Simulation & Scheduling Software

12:30pm-2:30pm/Veranda E

Teaching Simio Benefits

Simio Simulation & Scheduling Software

3:00pm-5:00pm/Veranda E

New Innovations: Cloud Computing, Real-Time Scheduling, Industry 4.0, and More

Rockwell Automation (Arena® Simulation Software)

10:00am-12:00pm/Veranda A

New Features and Capabilities in Arena 15.1

Special Events

New Attendee Orientation

If you are attending WSC for the first time, don't miss this informal and informative orientation on Sunday, 6:30pm-7:00pm, in Pavilion. Typically, over 30% of WSC attendees identify themselves as first-timers. The WSC '17 Committee will be on hand to answer your questions.

Exhibits

Take this opportunity to meet with vendors of simulation software, applications and services, and with representatives of simulation-related professional societies. Displays and demonstrations allow you to examine and compare many different products and services. You also have the chance to talk informally with the developers of leading simulation products. Exhibits are open:

Monday	9:30am-5:30pm
Tuesday	9:30am-5:30pm
Wednesday	9:00am-11:30am

Exhibitor directory and floor plan on pages 147-152.

Speaker Breakfast

Speakers and session chairs are invited and encouraged to attend a complimentary continental breakfast on the day of their presentation (7:00am-8:00am, Veranda). The breakfast provides an opportunity to get together with the chair and other speakers in your session to discuss the timing of presentations, handling of questions, and audio-visual plans. **Speakers and session chairs receive a breakfast ticket in their registration packets.** To locate your session table, look for the table sign indicating the track name.

Monday Evening Reception

Join us on Monday evening, 6:30pm-8:30pm in the Summerlin Ballroom BCDE for good food and camaraderie. The reception is a great place to meet with other simulation professionals, many of your old friends, and just relax and recharge for the rest of the week. Admission to the party is included in your registration fee; guest tickets are available at the WSC registration desk (\$20).

User Group Meetings

Plan to attend these informative meetings on Tuesday evening, 6:30pm-8:30pm.

<i>Group</i>	<i>Room</i>
AnyLogic Company	Veranda C
Applied Materials	Red Rock G
Simio Simulation & Scheduling Software	Pavilion
LLamasoft, Inc.	Hills

Sponsors

The Winter Simulation Conference 2017 expresses thanks to the organizations who have contributed direct financial support to help make this conference a success.

Platinum Sponsors



Modeling, Simulation & Visualization Engineering
odu.edu/msve



Gold Sponsor



Bronze Sponsors



Recruiter



Sponsoring Societies

- ACM/SIGSIM: Association for Computing Machinery: Special Interest Group on Simulation
- ASA: American Statistical Association, Technical Co-Sponsor
- ASIM: Arbeitsgemeinschaft Simulation, Technical Co-Sponsor
- IEEE/SMC: Institute of Electrical and Electronics Engineers: Systems, Man, and Cybernetics Society, Technical Co-Sponsor
- IISE: Institute of Industrial and Systems Engineers
- INFORMS-SIM: Institute for Operations Research and the Management Sciences: Simulation Society
- NIST: National Institute of Standards and Technology (NIST), Technical Co-Sponsor
- SCS: The Society for Modeling and Simulation International

Preface

From the General Chair

Welcome to the 2017 Winter Simulation Conference (WSC), an annual gathering of researchers and practitioners from around the world, and across industry, academia and the government.

This year we celebrate the 50th anniversary of the conference, which traces its lineage to the 1967 *Conference on the Applications of Simulation Using GPSS*. In addition to our traditional lineup of tracks, our Program Chair, **Gabriel Wainer**, has organized special program content both celebrating the history of simulation, and also looking forward into a future with *Simulation Everywhere!*

We have a great line-up of featured speakers this year. We begin with a conference keynote address from **Barry Nelson** who asks the question, *WSC 2067: What are the Chances?* This year, three of our tracks will feature keynotes as well. The keynote for our Military Applications and Homeland Security Track is **Douglas Hodson**, who examines *Military Simulation: a Ubiquitous Future*. Our MASM keynote speaker is **Stéphane Dauzère-Pérès**, speaking on *Achievements and Lessons Learned from a Long-Term Academic-Industrial Collaboration*. Our History of Simulation Track begins with a keynote address from **Brian Hollocks**, who reviews *A History of Simulation in the United Kingdom*. Finally, we are pleased to offer two lunchtime presentations in our Titans of Simulation series. **Bob Sargent** offers *A Perspective on Fifty-Five Years of the Evolution of Scientific Respect for Simulation* and **Bernie Zeigler** answers *Why Should We Develop Simulation Models in Pairs?*

How does a conference persist for fifty years? In large part, the longevity of WSC is attributable to the remarkable consistency and quality of the program and conference experience from year to year. As most of you know, this quality and consistency does not happen by accident. Conference planning and preparation is a 5-year process guided by the **WSC Board of Directors**, whose members represent our sponsoring societies. Members of the board typically serve 6-10 year terms, and often have served in conference organization roles prior to their service on the board. They provide the essential institutional memory that enables the continuity of the conference year after year. I am grateful to all of them for their support along the road to WSC 2017. In particular, I would like to acknowledge: our intrepid Board Liaison, **David Nicol**, for filling out all the sponsorship forms and fielding random questions and requests; **Ann Dunkin** (2013 Board Chair), who helped with the arduous task of scouting out locations for the conference; **Mike Kuhl** for his work on the awesome WSC mobile app; and **Jeff Smith** and **Jeff Joines**, who worked tirelessly to identify just the right course for the WSC golf tournament.

With the board's guiding hand, each conference is the result of the efforts of the conference committee. WSC 2017 has been fortunate to have a tremendous team of volunteers. I am profoundly grateful to each of them. Our Program Chair, **Gabriel Wainer**, has put in many long hours and organized a fantastic program. Our Proceedings Editors, **Wai Kin (Victor) Chan**, **Andrea D'Ambrogio**, **Gregory Zacharewicz** and **Navonil Mustafee**, have worked with our authors and publisher to produce a high-quality record of this landmark conference. Our Business Chair, **John Tufarolo**, kept us on track financially while ensuring we don't skimp on the coffee breaks! Exhibits Chairs, **Renée Thiesing** and **Jayne Talbot** organized a great collection of booths in the exhibit hall. Please visit there often! Our Sponsorship Chair, **Rene Reiter**, coordinated academic and corporate sponsorships of various items and attendee giveaways, including our nifty cooler bag! Our Registration Chairs, **Alice Smith** and **John Fowler**, ensured that all our authors were successfully registered and handled the processing of VISA letters, as needed, for our international attendees. Finally, our Publicity Chairs, **Christine Harvey**, **Steffen Strassburger**, **Rodrigo Castro**, and **YB Kim**, did a fantastic job publicizing the conference through surface and electronic mail, and our social media presence on LinkedIn, Facebook and Twitter.

In addition to our hard working volunteers, WSC enlists the professional services of **Omnipress**, our publisher, **Linklings**, our web-based paper management partners, and **INFORMS**, for our web site and conference management services. A very special thanks to **Liz Hood** for her support to the conference. We could not have done this without her!

Before I leave the stage, a tip-of-the-cap to **Dick Nance**, who brought me along as a graduate student to my first WSC in 1989. And a heartfelt thank you to the many WSC board members I served with during my 12 years on the board. It was a privilege to work with each of you in service of this amazing conference.

Finally, thanks to all our authors, referees, track chairs, session chairs, and attendees. For many of you WSC is an anticipated annual reunion with colleagues and friends. For some of you, this is your very first WSC. Welcome! I hope you are pleased with the experience. My fondest wish for you is that someday you will be a WSC “old timer” like me!

Ernest H. Page
WSC 2017 General Chair

From the Program Chair

It is time for Simulation Everywhere!

In the last 50 years, we moved from researching ad-hoc simulation techniques in single-user single-processor digital computers, to modeling and simulation embedded in specialized hardware, distributed in multiple heterogeneous processors, both locally and remotely, in virtual and real time, in tiny or supercomputers. The Winter Simulation Conference (WSC) has witnessed this evolution, and it now continues being the premier international forum for scientists and professionals in modeling and simulation.

It has been an honor to have the chance to coordinate the scientific program for this special 50th-anniversary. The results of the efforts of all the participants can be seen in the high quality of the Proceedings. The Program for WSC 2017 includes three categories of articles: contributed full papers, invited full papers and extended abstracts. The papers in the first two categories were rigorously reviewed and they will be archived in both the IEEE and ACM Digital Libraries. This year, 358 contributed full papers were submitted for review, of which 234 (or 65%) are published. In addition, 147 invited full papers were submitted for review, of which 134 (or 91%) are published, bringing the total number of full paper submissions to 504. The 368 selected, peer-reviewed papers constitute the core of the WSC 2017 Program. The third category of submissions consists primarily of extended abstracts for the Poster, Industrial Case Studies, and Vendor tracks, as well as the PhD colloquium. These submissions are not published within IEEE and ACM; however, they are available within the program and the WSC Web Archive. This year, the number of submissions in this category was 135. Of these, 107 (or 81%) will be presented at the conference. In summary, WSC 2017 had 640 submissions, out of which 475 made it into the Program. The articles were authored by 1166 different researchers from 36 countries in five Continents.

Within the program, the invited and contributed papers have been organized into 22 tracks. This year we have a special track on the History of Simulation, organized by **Bob Sargent**, which is devoted to celebrate the 50 years of WSC. Our Keynote Speaker, **Barry Nelson** will also open the discussion about the Future of Simulation, another track for 2017. There are two tutorial tracks: Introductory and Advanced. The key modeling and methods tracks include agent-based simulation, modeling methodology, cyber-physical systems, intelligent, adaptive and autonomous systems and hybrid simulation. The key analysis tracks include simulation optimization and analysis methodology. The key application oriented tracks include architecture and construction, aviation modeling and analysis, environmental and sustainability applications, healthcare applications, logistics, supply chain modeling and transportation, manufacturing applications, military and homeland security, simulation education, and social and behavioral simulation. The WSC continues its long relationship with MASM, Modeling and Analysis of Semiconductor Manufacturing. There are special panels on innovation in M&S in the last 50 years, hybrid simulation, and computing challenges and opportunities, human simulation, and thinking and learning through M&S.

Two tracks included on Sunday are the PhD colloquium and the poster briefing. Posters from these two tracks will be on display Sunday later afternoon after presenters provide overviews on Sunday during the afternoon. They provide forums for researchers and students to discuss their work, and they will remain available during the conference. Practitioners will exchange ideas within Industrial Case Studies Track. Vendors will present their latest tools and techniques in the vendor track during the main conference, as well as in workshops on Sunday.

The high quality of the WSC program could not be accomplished without the hard work of the program committee, track coordinators, and reviewers. We conducted 1579 reviews of high quality, from 59 Track Chairs, their 293 Track Program Committee Members and other 107 External Reviewers. You will find a list of all the track coordinators towards the end of the program booklet. My sincerest thanks for all of their hard work. I would also like to thank **Stephen Chick** and **Jeff Joines** for their guidance and support, and **David Goldman** who was always ready to help doing tasks outside the scope of his track. In addition, I would like to thank the proceedings team, **Victor Chan**, **Andrea D’Ambrogio**, **Navonil Mustafee** and **Gregory Zacharewicz** for their dedicated service to the

quality of the WSC proceedings. It was a pleasure to collaborate with Victor, who led the team that was responsive and effective, and worked tirelessly to ensure the high quality of the papers in the conference. Likewise, the extreme dedication of track chairs in ensuring the quality of the materials and the prompt response to all the questions to the authors is invaluable. Notably, **Markus Rabe** and again **Dave Goldman**, in charge of the Logistics, SCM and Transportation track, were always ready in advance, and provided good ideas that were shared with the rest of the tracks. The History of Simulation track, led by **Bob Sargent** took over two years of hard work and dedication and detailed coordination for this special anniversary. In addition, without the support of **Mark Montague** at Linklings, it would have been impossible to complete the many tasks necessary within the Paper Management System. I would like thanks the great work of **Liz Hood**, and that of the **WSC board**, led by **Lin Uhrmacher**. Finally, I would like to thank our General Chair, **Ernie Page**. I was elated when six years ago he invited me to be the Program Chair of the conference. He told me it was going to be a lot of work, but I was excited to do it. Thanks to the great work of all the volunteers, it has been easier than I expected, and I thank Ernie for giving me the opportunity. My first Wintersim was in 2001, and I was fascinated with the quality of the research presented. Thanks Ernie, for letting me experiencing this fascination once again, from the other side of the looking glass. I hope that one day I will be an “old timer” too.

It has been an honor and a pleasure.

Gabriel A. Wainer
WSC 2017 Program Chair

From the Editors

Over the past 50 years, WSC has been the premier Modeling & Simulation forum that brings together scholars and practitioners that collectively aim to advance the state-of-the-art and practice in computer simulation. It was a privilege for all of us to contribute to these special 50th-anniversary proceedings as editors. This year’s proceedings not only inherit WSC’s excellence in delivering a broad spectrum of simulation-related research and applications, but also include a special track: the History of Simulation track, organized by Professor **Robert G. Sargent**, to celebrate the 50th birthday of WSC. This track has 24 articles written by pioneers and experts in simulation. These articles detail the history of simulation development around the world, major milestones and activities, interactions with other fields, and highlights of interesting findings about simulation research and applications. This year’s proceedings promise to make WSC a unique and dynamic event that cultivates interaction between members of distinct disciplines from natural, physical, and social sciences to engineering to art. With this year’s emphasis on having *Simulation Everywhere!*, the intellectual merit and broader impacts of Modeling & Simulation on our society will be further explored and showed case to the general public.

Many people contributed to making WSC 2017 a success. Our thanks go first and foremost to authors and co-authors for not only choosing WSC as an outlet for disseminating their research, but also for their patience and help in getting the papers to a common format. Without their diligence and responsiveness, we could not have produced these proceedings. The program includes over 360 full papers distributed over 23 tracks, 16 vendor abstracts or papers, and 33 industrial case studies. All accepted papers will be submitted and published in both the ACM and IEEE Digital Libraries. The remaining materials will also be available through the WSC web archive and hence be indexed and become accessible via Google Scholar. Our poster session will include 32 posters, and their presenters will have an opportunity to share their work-in-progress and receive valuable feedback from the conference attendees. Such interactions are expected to lead to potential avenues for future collaborations. This year, 26 Ph.D. students will be competing in the Doctoral Colloquium for the best paper awards, which will be presented by ACM/SIGSIM and INFORMS Simulation Society.

The efforts of the track chairs, track program committees, and referees were instrumental in shaping the program by facilitating the peer-review process and hence supporting a high quality conference. We also would like to acknowledge the support provided by the **Linklings** team in helping us to improve our ability to manage the papers and streamline the editorial process. As the WSC 2017 editorial team, we hope everyone enjoys this year’s outstanding program.

Wai Kin (Victor) Chan
Andrea D'Ambrogio
Gregory Zacharewicz
Navonil Mustafee
WSC 2017 Proceedings Editors

Tribute to Julian Reitman

Appreciation of Julian Reitman, Simulation Pioneer and Leader of the Winter Simulation Conference



Over the past seven decades, Julian Reitman has made major contributions to the field of computer simulation and to the establishment and advancement of the Winter Simulation Conference (WSC). This appreciation of Julian highlights various facets of his remarkable professional career, including his numerous technical contributions as well as his contributions in service to WSC and the international simulation community.

CAREER OVERVIEW

From the late 1940s through the 1950s, Julian worked on the design of electro-acoustic test equipment as well as a real-time airline reservation system that was capable of handling extended periods of peak loading while operating around the clock. These experiences convinced him of the urgent need for significantly more effective tools to simulate such complex systems on a digital computer.

In the early 1960s he led pioneering applications of the original General Purpose Simulation System (GPSS) in a broad diversity of disciplines ranging from the design of computer-based telecommunication systems to military effectiveness studies of carrier-based aircraft operations; and some of the resulting simulation models evolved and remained in use for almost three decades. In the late 1960s, Julian led the development of the GPSS/360–Norden and GPSS V–Norden simulation languages, incorporating innovations that were decades ahead of their time, including (i) memory management facilities for executing a large-scale simulation, possibly requiring access to a large database; and (ii) graphical, interactive facilities for debugging, animating, monitoring, and controlling the execution of a large-scale simulation model. In 1965, he was one of the founders of the Systems Science and Cybernetics Group (now the Systems, Man, and Cybernetics Society) of the Institute of Electrical and Electronics Engineers (IEEE), serving as a member of its administrative committee (1967) and as chair (1969) of that organization. Subsequently he served the larger IEEE organization in several editorial and administrative positions; and in recognition of this long-standing service, he was named a Senior Life Member of IEEE.

Julian is one of the founders of the Winter Simulation Conference (WSC), serving as its first program chair (1967), its second general chair (1968), and the longest serving member of the WSC Board of Directors (1967–1985). He also led the effort to secure sponsorship of the 1967 conference by IEEE and its IEEE Systems Science and Cybernetics Group.

He has made significant contributions to the simulation literature since the early 1960s:

- He has written a series of archival journal articles and proceedings papers on innovative applications of simulation and on simulation languages.
- He edited a special issue of the *IEEE Transactions on Systems Science and Cybernetics* (Volume SSC-4, Number 4, November 1968) that documented some of the presentations given at the 1967 predecessor of WSC.
- He was recognized at WSC '07 in a special session titled “Fortieth Anniversary Special Panel: Landmark Papers” for the following article:

Reitman, J., D. Ingerman, J. Katzke, J. Shapiro, K. Simon, and B. Smith. 1970. “A Complete Interactive Simulation Environment: GPSS/360–Norden.” In *Proceedings of the Fourth Annual Conference on Applications of Simulation*, edited by P. J. Kiviat and M. Araten, 260–270.

Because of their long-term impact on simulation practice, theory, and education, ten epoch-making articles were selected for this session from four decades of WSC *Proceedings* articles. In Reitman et al. (1970), Julian and his collaborators pioneered the use of animation and visually based data management tools long before the availability of personal computers and software for animation and spreadsheets.

- He wrote the now-classic simulation textbook *Computer Simulation Applications: Discrete-Event Simulation for Synthesis and Analysis of Complex Systems* (Wiley-Interscience, 1971).
- He served on the editorial board of the IEEE Press, the *IEEE Transactions on Systems Science and Cybernetics*, the *IEEE Transactions on Systems, Man, and Cybernetics*, and the *ACM Transactions on Modeling and Computer Simulation*.

Since the mid-1980s, Julian has focused much of his effort on the history of science and technology, including the history of simulation and WSC as documented in the following:

- His 1988 WSC Keynote Address and *Proceedings* article titled “A Concise History of the Ups and Downs of Simulation”;
- His 1992 WSC *Proceedings* article titled “Twenty-Fifth Panel Discussion: The Winter Simulation Conference: Perspectives of the Founding Fathers” (with Michel Araten, Harold G. Hixson, Austin C. Hoggatt, Philip J. Kiviat, Michael F. Morris, Arnold Ockene, and Joseph M. Sussman);
- His 2017 WSC *Proceedings* article titled “History of the Winter Simulation Conference: Origins and Early Years (1967–1974)” with Thomas J. Schriber, Arnold Ockene, and Harold G. Hixson.

Julian has also taught numerous undergraduate and graduate courses on the history of science and technology at the University of Connecticut, Stamford (1987–1995), George Mason University (1988–1990), and other institutions.

Taken as a whole, Julian Reitman’s professional contributions to the field of simulation are striking not only for their impact on the field and on the Winter Simulation Conference but also for the remarkably long time period over which that impact has been sustained. He is an inspiration and role model to everyone whose life he has touched.

50th ANNIVERSARY KEYNOTE ADDRESS

***Monday, 8:00a.m.-9:30a.m.
Summerlin Ballroom BCDE***

WSC 2067: What Are The Chances?



Barry L. Nelson

Walter P. Murphy Professor, Department of Industrial Engineering & Management Sciences, Northwestern University

At the November 1967 “Conference on the Applications of Simulation Using GPSS” it seems unlikely that anyone was wondering if the conference would still be occupying a big hotel in 2017. Conferences persist for many

reasons, but a technical conference like WSC has to remain relevant to users, vendors, researchers and consumers (not just hotels) to survive. If our kind of simulation vanished, then so (eventually) would WSC. What is required for simulation to “remain relevant” for the next 50 years? Without fear of having to answer for my crimes in 2067, I boldly speculate on what **SHOULD** matter for the next 10-20 years, if not the next 50, with a focus on our strength: dealing with uncertainty

Barry L. Nelson is the Walter P. Murphy Professor of the Department of Industrial Engineering and Management Sciences at Northwestern University and a Distinguished Visiting Scholar at Lancaster University in England. His research focus is on the design and analysis of computer simulation experiments on models of discrete-event, stochastic systems, including methodology for simulation optimization, quantifying and reducing model risk, variance reduction, output analysis, metamodeling and multivariate input modeling. His application areas are manufacturing, services, financial engineering and transportation. He has published numerous papers and three books, including *Foundations and Methods of Stochastic Simulation: A First Course* (Springer, 2013). Nelson is a Fellow of INFORMS and IIE. In 2006, 2013 and 2015 he received the Outstanding Simulation Publication Award from the INFORMS Simulation Society, and in 2009, 2011 and 2015 he was awarded the Best Paper–Operations Award from IIE Transactions. His teaching has been acknowledged by a Northwestern University Alumni Association Excellence in Teaching Award, a McCormick School of Engineering & Applied Science Teacher of the Year Award, and the IIE Operations Research Division Award for Excellence in the Teaching of Operations Research. Further information, including a complete CV, can be found at <http://www.iems.northwestern.edu/~nelsonb/>. His email address is nelsonb@northwestern.edu.

50th ANNIVERSARY TITANS OF SIMULATION

Monday, 12:20p.m.-1:20p.m.

Summerlin Ballroom BCDE

Why Should We Develop Simulation Models in Pairs?



Bernard P. Zeigler

Professor Emeritus of Electrical and Computer Engineering, University of Arizona

The conventional approach to model construction for simulation is to focus on a single model and follow a more or less structured development cycle. Why we put in twice the time and effort to develop two models rather than one? The answer lies in the fact that like most greedy heuristics, short-sightedness at the beginning may be much more costly in the end. This talk will champion the cause of the pairs-of-models (perhaps families of models) with discussion of multiresolution modeling. We show how the pair-of-models approach leads to better results overall than construction of a complex model followed by a simpler model developed subsequently by necessity under stress when complexity overwhelms. Benefits include the ability to perform mutual cross-calibration, avoiding the usual difficulties in harmonization of the underlying ontologies as well as ability to better reconcile and correlate predictions of referent system outcomes.

Bernard P. Zeigler is Chief Scientist at RTSync Corp., Professor Emeritus of Electrical and Computer Engineering at the University of Arizona (UA) and Affiliated Research Professor in the C4I Center at George Mason University. He is internationally known for his seminal contributions in modeling and simulation theory. He has published several highly cited books including “Theory of Modeling and Simulation” (3rd edition in process) and “Guide to Modeling and Simulation of Systems of Systems.” He is the originator of the Discrete Event System Specification (DEVS) formalism in 1976 which has spurred the development of a world-wide research community, with its own conference meetings, and research/technology awards. In 1995, Zeigler was named Fellow of the IEEE in recognition of his contributions to the theory of discrete event simulation. Dr. Zeigler co-founded the Arizona Center for Integrative Modeling and Simulation (ACIMS) in 2001 dedicated to the development of modeling and simulation as a discipline of the future. Dr. Zeigler has been the lead architect of multiple web-based systems in complex systems that incorporate unique behaviors derived from DEVS-based properties. He is also Fellow of the Society for Modeling and Simulation International and member of its Hall of Fame. He received the Life-time Achievement Award from INFORMS in 2016. His email address is zeigler@ece.arizona.edu.

50th ANNIVERSARY TITANS OF SIMULATION

Tuesday, 12:20p.m.-1:20p.m.

Summerlin Ballroom BCDE

A Perspective on Fifty-Five Years of the Evolution of Scientific Respect for Simulation



Robert G. Sargent

Professor Emeritus, Syracuse University

This presentation will give a personal perspective on the evolution of how discrete-event simulation moved from having an image from the 1950s through the 1980s of being a “brute force programming effort” and as a problem solving “method of last resort” to today’s status where simulation enjoys “considerable scientific respect” as simulation is often the solution “method of choice” and has much “scholarly respect”. This evolution changed simulation from using “ad hoc methods” of solution on “early digital computers” to using simulation software systems containing “science-based methods” of solution on “modern day computers”.

Robert G. Sargent is a Professor Emeritus at Syracuse University. He has made numerous contributions to the simulation community in the forms of both service work and scholarly publications. His many honors and awards include being a recipient of the 1988 Distinguished Service Award and the 2002 Lifetime Professional Achievement Award from INFORMS Simulation Society (I-SIM), the 2010 Board of Directors James R Wilson Award and the 40th Anniversary Landmark Paper Award from Winter Simulation Conference (WSC), and the 2012 Distinguished Contributions Award from ACM/SIGSIM. Moreover, he was elected a Fellow of INFORMS in 2005. He initiated the rebirth of the WSC in 1976, was General Chair of the 1977 WSC, and served on the Board of Directors of WSC for 10 years. Furthermore, he was the Founding President of the WSC Foundation, served as President of The Institute of Management Sciences College on Simulation (now I-SIM), and initiated the establishment of the Computer Simulation Archive. His email address is rsargent@syr.edu.

MILITARY KEYNOTE

Monday, 10:00a.m.-11:30a.m.

Charleston A

Military Simulation: A Ubiquitous Future



Douglas D. Hodson

Associate Professor, Software Engineering, Air Force Institute of Technology (AFIT)

The Department of Defense uses Modeling and Simulation to support a variety of activities ranging from engineering to theater-level analytical studies, training, strategy evaluation and test. This talk presents some of the current challenges, research directions and promising opportunities to further exploit this powerful tool to understand complex system dynamics and predict performance.

Douglas D. Hodson is an Associate Professor of Software Engineering with the Air Force Institute of Technology. He received a B.S. in Physics from Wright State University in 1985, and both an M.S. in Electro-Optics in 1987 and an M.B.A. in 1999 from the University of Dayton. He completed his Ph.D. at the Air Force Institute of Technology in 2009. He has over 25 years of experience in the domain of modeling and simulation, including mixed reality and distributed virtual simulations. He is active in the 9-University Science of Test Research Consortium supported by the Office of Secretary of Defense leading the work in the Live, Virtual and Constructive simulation initiative and is the lead technical developer and project manager for the open-source Mixed Reality Simulation (MIXR) Platform which has been used to develop a wide variety of standalone and distributed simulation applications. His email address is douglas.hodson@afit.edu.

HISTORY OF SIMULATION KEYNOTE

*Monday, 1:30p.m.-2:30p.m.
Trails*

History of Simulation in the UK



Brian W. Hollocks

Professor, Bournemouth University, Faculty of Management

Discrete-event simulation first emerged in the late 1950s and grew in popularity steadily to become the most frequently used of the classical Operational Research techniques across a range of industries and users. The leading advances in the evolution of discrete-event simulation

software came from the UK and the USA and the author was engaged for some 30 years with its development and use. The paper reviews that history as a first-hand account, specifically in the UK and focusing on the period to 1994.

Brian Hollocks is in the process of retiring as Professor of Management Science at Bournemouth University whom he joined in 1994 as the INTEL Chair in Computer Supported Co-operation. His lecturing and research included simulation, computer supported cooperative work, knowledge management, and artificial intelligence. Prior to being an academic, he was in business and industry, primarily in operational research and software development/marketing. This included some 30 years in the development and use discrete-event simulation software systems. He is a Mechanical Engineering graduate and holds a PhD in Management Science from Southampton University. His email address is brian.hollocks@gmail.com.

MASM KEYNOTE

Tuesday, 3:30p.m.-5:00p.m.

Veranda E

Achievements and Lessons Learned from a Long-term Academic-Industrial Collaboration



Stéphane Dauzère-Pérès

Professor, Ecole des Mines de Saint-Etienne

Stéphane had the opportunity to work for about 14 years on many different projects with two manufacturing sites of the French-Italian semiconductor company STMicroelectronics. Supported by European, national and industrial projects, this still active long-term academic-industrial collaboration led to many scientific and industrial achievements, spreading to other companies. Through regular exchanges, engineers, researchers, PhD and Master students were able to present their problems, their advances and generate new research projects. After some history of the collaboration, the presentation will survey some of the main research and industrial results in qualification and flexibility management, production and capacity planning, scheduling, automated transportation, dynamic sampling and time constraint management. Challenges faced and lessons learned when applying Operations Research and Industrial Engineering in practice, and in particular in semiconductor manufacturing, will be discussed. Benefits for both practitioners and researchers will be emphasized, such as the opportunity to propose and study new relevant problems and develop and apply novel approaches using actual industrial data.

trial achievements, spreading to other companies. Through regular exchanges, engineers, researchers, PhD and Master students were able to present their problems, their advances and generate new research projects. After some history of the collaboration, the presentation will survey some of the main research and industrial results in qualification and flexibility management, production and capacity planning, scheduling, automated transportation, dynamic sampling and time constraint management. Challenges faced and lessons learned when applying Operations Research and Industrial Engineering in practice, and in particular in semiconductor manufacturing, will be discussed. Benefits for both practitioners and researchers will be emphasized, such as the opportunity to propose and study new relevant problems and develop and apply novel approaches using actual industrial data.

Stéphane Dauzère-Pérès is Professor at the Center of Microelectronics in Provence (CMP) of Mines Saint-Etienne in France and Adjunct Professor at BI Norwegian Business School in Norway. His research interests broadly include modeling and optimization of operations at various decision levels (from real-time to strategic) in manufacturing and logistics, with a special emphasis on semiconductor manufacturing. He has published more than 65 papers in international journals. He has coordinated multiple academic and industrial research projects. He was runner-up in 2006 of the Franz Edelman Award Competition, and won the Best Applied Paper of the Winter Simulation Conference in 2013. His email address is dauzere-peres@emse.fr.

VENDOR TRACK ABSTRACTS

Monday 10:00a.m.-11:30a.m.

VENDOR / CHARLESTON D

Anylogic / Arena

New Features and Capabilities in Arena 15.1 / Robert Kranz and Nancy B. Zupick (Rockwell Automation)

Arena 15.1 was released to the market earlier this year. This latest release of Arena includes a number of advancements designed to enhance ease-of-use, make complex simulations easier and expand the overall simulation capabilities of Arena. This presentation will cover those enhancements and provide demonstrations on how to make the most of these new capabilities.

Multimethod Simulation and Analytics for the Entire Business Lifecycle / Derek Magilton and Arash Mahdavi (AnyLogic Company)

AnyLogic Company produces the standard in multimethod modeling technology which equates to increased efficiency and less risk when tackling complex business challenges. This unmatched flexibility is found in all AnyLogic products allowing users to capture the complexity of virtually any system, at any level of detail, and gain deeper insight into the interdependent processes inside and around an organization.

Experience the latest business challenges solved using AnyLogic Simulation Software and anyLogistix Supply Chain Software in Cardinal Health, CSX, DHL, Deloitte, GE, GlaxoSmithKline and more.

VENDOR / CHARLESTON F

Simio / PTV Group

Introduction to Simio / Katie Prochaska and Renée Thiesing (Simio LLC)

This paper describes the Simio modeling system that is designed to simplify model building by promoting a modeling paradigm shift from the process orientation to an object orientation. Simio is a simulation modeling framework based on intelligent objects. The intelligent objects are built by modelers and then may be reused in multiple modeling projects. Although the Simio framework is focused on object-based modeling, it also supports a seamless use of multiple modeling paradigms including event, process, object, systems dynamics, agent-based modeling, and Risk-based Planning and scheduling (RPS).

Connected Autonomous Vehicle (CAV) Simulation Using PTV Vissim / Alastair Evanson (PTV Group)

Currently there is a lack of detailed understanding regarding the effect of autonomous vehicles on traffic operations and transportation infrastructure. PTV Vissim, the world's leading microscopic traffic simulation tool, provides a virtual testbed to evaluate the coexistence of autonomous and conventional vehicles either in the transition phase or when vehicle fleets are fully autonomous. Vissim traffic simulation is increasingly being employed to address the evidence gap around the potential impacts of disruptive technologies, such as connected autonomous vehicles, on traffic flow and capacity. Incorporating hardware in the loop testing allows detailed representation of autonomous vehicle control algorithms, sensor and communication protocols to be simulated within a realistic virtual traffic environment. Simulating varying penetration rates of autonomous vehicles, and different behavioral characteristics such as platooning, vehicle to vehicle communication and vehicle to infrastructure communication, has demonstrated the opportunity to reduce travel times by 11% and delays by more than 40%.

Monday 1:30p.m.-3:00p.m.

VENDOR / CHARLESTON D

Mosimtec / Frontline Systems

Key Considerations For Starting Or Maintaining Your Simulation Department / Amy B. Greer (MOSIMTEC, LLC)

Organizations interested in applying simulation to support informed decision-making need to make a key decision whether to contract the work or develop an internal capability to perform the work. Both alternatives have its pros and cons and the ideal approach varies across organizations. This presentation reviews some of the key factors worth consideration, including the caliber of staff, costs, risks, and necessary and perceived internal focus. Furthermore, managers and developers have different responsibilities and challenges in ensuring a successful project, very much influenced by the structure of the simulation work being performed. The presenters will share experiences working both in an internal simulation role and working as external service providers.

Simulation Models in Excel, Tableau, Power BI and Mobile Apps with Analytic Solver® Software / Daniel H. Fylstra (Frontline Systems, Inc.)

Deploying simulation models to “business consumers” is now easier than ever. Analytic Solver® software offers a simple, point-and-click way to create and test analytic models using your web browser or your Excel spreadsheet – then, with just a few mouse clicks, make those models run in Tableau and Power BI dashboards. Your models can connect to any Tableau or Power BI data source, display results using charts and tables, and they’ll re-run whenever the data changes. If you’d rather deploy models on your own website, or in your mobile app, that is surprisingly easy as well. With powerful tools for Monte Carlo simulation and risk analysis, conventional and stochastic optimization, forecasting, data mining and text mining built in, you can use Analytic Solver to quickly build and deploy models that yield real business impact. We’ll demonstrate these capabilities in our Vendor Tutorial session at WSC 2017.

VENDOR / CHARLESTON F

SAS / MATLAB

Looking Beyond the Model: Data Input, Collection, and Analysis with SAS® Simulation Studio / Edward P. Hughes and Emily K. Lada (SAS Institute Inc.)

Discrete-event simulation as a methodology is often inextricably intertwined with many other forms of analytics. Source data often must be repaired or processed before being used (indirectly or directly) to characterize variation in a simulation model. Collection of simulated data needs to coordinate with and support the evaluation of performance metrics in the model. Or it might be necessary to integrate other analytics into a simulation model to capture particular complexities in the real world system. We show how SAS Simulation Studio, as an integral part of the SAS analytic ecosystem, enables you to tackle all of these challenges. You have full control over the use of input data and the creation of simulated data. Strong experimental design capabilities mean you can simulate for all needed scenarios. Additionally, you can embed any SAS analytic program—optimization, data mining, or otherwise—directly into the execution of your simulation model.

Using MATLAB to build simulations and learn from them in the classroom / Teresa Hubscher-Younger and Mary Fenelon (MathWorks)

This presentation shows how to use MATLAB and its simulation tools Simulink and SimEvents to build hybrid simulations, such as a simulation for estimation production throughput and scheduling. Then, we show how to use MATLAB tools for statistics, machine learning, and optimization to understand the model, as well as use the model to make decisions. We show how to use Live Scripts and Apps for interactive lectures. We also show how to access MATLAB Online through a browser or MATLAB Mobile from your phone. Create and grade assignments with Cody Coursework.

Monday 3:30p.m.-5:00p.m.

VENDOR / CHARLESTON F

Simio / Automod

The Application of Simio Scheduling in Industry 4.0 / Gerrit Zaayman and Anthony Innamorato (Simio LLC)

Simulation has traditionally been applied in system design projects where the basic objective is to evaluate alternatives and predict and improve the long term system performance. In this role, simulation has become a standard business tool with many documented success stories. Beyond these traditional system design applications, simulation can also play a powerful role in scheduling by predicting and improving the short term performance of a system. In the manufacturing context, the major new trend is towards digitally connected factories that introduce a number of unique requirements which traditional simulation tools do not address. Simio has been designed from the ground up with a focus on both traditional applications as well as advanced scheduling, with the basic idea that a single Simio model can serve both purposes. In this paper we will focus on the application of Simio simulation in the Industry 4.0 environment.

Automod®: Performance, Scalability and Accuracy / Daniel Muller (Applied Materials)

Managers need state-of-the-art tools to help in planning, design, and operations. The AutoMod product suite from Applied Materials has been used on thousands of projects empowering engineers and managers to make the best decisions. AutoMod's capability to model large complex automation and material handling systems continues to lead the market. Hierarchical model construction allowing users to reuse model components, decreasing the time required to build models. Recent enhancements to AutoMod's material handling systems have increased modeling accuracy and ease-of-use. These advances have made AutoMod one of the most widely used simulation packages. AutoMod's power lies in its performance, scalability and accuracy in detailed modeling of large and complex manufacturing, distribution, automation and logistic operations, leaving the competition behind. Come see the latest release and exciting plans for AutoMod's future and why it has outlasted the competition.

VENDOR / CHARLESTON D

VMS Solutions / Anylogic

Smart Scm Framework with Mozart / Keyhoon Ko (VMS Global, Inc) and Seungyoung Chung and Byung H. Kim (VMS Solutions Co. Ltd.)

Transparency is an essential attribute to meet the business objectives if the production is made under complex supply chain. At the same time, it is difficult to achieve if the production requires complex processes like semiconductor manufacturing or tons of sub-parts such as ship building and offshore industry. MOZART has been implemented in semiconductor, display panel, and tire industries as a planning and scheduling system. It covers weekly planning (Master Plan: MP), daily planning (Factory Plan: FP), and real time scheduling for these double-digit-day cycle time product manufacturing. MOZART extended the coverage to meet offshore project whose cycle time is several hundreds of days.

Integrating Artificial Intelligence with Anylogic Simulation / Lyle Wallis (PwC)

Simulation is one of five key technologies that PwC's Artificial Intelligence Accelerator lab uses to build Artificial Intelligence (AI) applications. Application of AI is accelerating rapidly, spawning new sectors, and resulting in unprecedented reach, power, and influence.

Simulation explicitly captures the behavior of agents and processes that can either be described by or replaced by AI components. AI components can be embedded into a simulation to provide learning or adaptive behavior. In addition, simulation can be used to evaluate the impact of introducing AI into a "real world system" such as supply chains or production processes. In this workshop, we will demonstrate an Agent-Based Model with Reinforcement Learning for Autonomous Fleet Coordination; demonstrate and describe in detail a version of the AnyLogic Consumer Market Model that has been modified to include adap-

tive dynamics based on deep learning; and describe approaches to integrating machine learning to the design and development of simulations.

Tuesday 8:00a.m.-9:30a.m.

VENDOR / CHARLESTON D

Arena / Automod

Arena and Industry 4.0 / Robert A. Kranz and Nancy B. Zupick (Rockwell Automation)

Industry 4.0, the Industrial Internet of Things, Smart Factories. These all describe the initiatives companies are undertaking to combine information from varied sources to make better decisions for their businesses and their customers. Rockwell Automation is at the forefront of these initiatives. In this presentation, we will discuss the role of Arena simulation software in this field and share some examples of how companies are making use of this today.

Automod®: Performance, Scalability and Accuracy / Daniel Muller (Applied Materials)

Managers need state-of-the-art tools to help in planning, design, and operations. The AutoMod product suite from Applied Materials has been used on thousands of projects empowering engineers and managers to make the best decisions. AutoMod's capability to model large complex automation and material handling systems continues to lead the market. Hierarchical model construction allowing users to reuse model components, decreasing the time required to build models. Recent enhancements to AutoMod's material handling systems have increased modeling accuracy and ease-of-use. These advances have made AutoMod one of the most widely used simulation packages. AutoMod's power lies in its performance, scalability and accuracy in detailed modeling of large and complex manufacturing, distribution, automation and logistic operations, leaving the competition behind. Come see the latest release and exciting plans for AutoMod's future and why it has outlasted the competition.

VENDOR / CHARLESTON F

Llamasoft / Flexsim

Future Simulation With Llamasoft / Steve Sommer and Don Hicks (Llamasoft)

Llamasoft, the global leader in Supply Chain Design, will be making a major announcement about the future of simulation. In our experience a large number of simulation studies end with good modeling and a bevy of data, but do not lead to driving changes in the business. To that end the presentation will explore the future of simulation optimization capabilities, scaling simulation to meet big data needs, using simulation to provide actionable information not just data to a user, and simulation in a cloud environment with the goal of driving impactful change to the business.

Modeling, Simulation and Analysis with FlexSim / Bill Nordgren (FlexSim Software Products, Inc.)

FlexSim is excited to unveil FlexSim 2018 at the Winter Simulation Conference, where we will showcase the latest features in our flagship simulation modeling software. For the past year, we've continued to innovate and develop the most capable and easy-to-use simulation solutions available. Join us for actual examples of how FlexSim has been used to solve problems in manufacturing, healthcare, and logistics. We'd love to show you how FlexSim is the right fit for your simulation needs.

Final Program Abstracts

Sunday 1:00p.m.-2:00p.m.

PHD COLLOQUIUM / TRAILS

Ph.D. Colloquium Keynote

Emily Lada (SAS Institute Inc.)

Recent Lessons on Research Ethics and Academic Publishing / James R. Wilson (North Carolina State University)

The focus of this presentation is on the basic principles of research ethics as they apply to writing and refereeing archival journal articles and conference proceedings papers. Although these principles have not changed substantially over time, in the last several years the emphases in practical applications of these principles have shifted in response to rapid changes in academic publishing and changing norms of performance in different disciplines. The discussion highlights recent lessons learned from these changes, especially as they apply to the field of computer simulation.

James R. Wilson is a professor in the Edward P. Fitts Department of Industrial and Systems Engineering at North Carolina State University. His current research interests are focused on probabilistic and statistical issues in the design and analysis of simulation experiments. He has held the following editorial positions: departmental editor of Management Science (1988–1996); area editor of ACM Transactions on Modeling and Computer Simulation (1997–2002); guest editor of a special issue of IIE Transactions honoring Alan Pritsker (1999–2001); and Editor-in-Chief of ACM Transactions on Modeling and Computer Simulation (2004–2010). He served The Institute of Management Sciences College on Simulation (now the INFORMS Simulation Society) as secretary-treasurer (1984–1986), vice president (1986–1988), and president (1988–1990). His activities in the Winter Simulation Conference (WSC) include service as proceedings editor (1986), associate program chair (1991), and program chair (1992). During the period 1997–2004, he was a member of the WSC Board of Directors corepresenting the INFORMS Simulation Society; and he served as secretary (2001), vice chair (2002), and chair (2003). During the period 2006–2009, he was a trustee of the WSC Foundation, serving as secretary (2006), vice-president (2007), and president (2008). Currently he is serving on the INFORMS Publications Committee. He is a member of ACM and ASA, and he is a fellow of IIE and INFORMS. His e-mail address is jwilson@ncsu.edu, and his web address is <http://www.ise.ncsu.edu/jwilson>.

Sunday 2:15p.m.-3:45p.m.

PHD COLLOQUIUM / TRAILS

Ph.D. Colloquium Presentations I

Weiwei Chen (Rutgers University)

A Multi-objective Perspective on Robust Ranking and Selection / Weizhi Liu (National University of Singapore)

In this study, we consider the robust Ranking and Selection problems with input uncertainty. Instead of adopting the minimax analysis in the classical robust optimization, we propose a novel method to approach this problem from the perspective of multi-objective optimization and Pareto optimality. The performances of each design under various scenarios are reformulated as multiple objectives, and in this case, robust Ranking and Selection becomes a multi-objective Ranking and Selection. In order to determine the number of simulation replications to various scenarios of each design, a bi-level convex optimization is formulated by maximizing the surrogate of the large deviation rate function of the probability of false selection (P(FS)). Numerical results show the efficiency of the proposed procedure (PR-OCBA) compared with other methods.

Analyzing Different Dispatching Policies for Probability Estimation in Time Constraint Tunnels in Semiconductor Manufacturing / Alexandre Lima (ST MICROELECTRONICS, Ecoles des Mines de Saint-Etienne)

In a High Mix/Low Volume(HM/LV) 300 mm wafer fabrication facilities, several hundred product routes are active, each involving dozens of Time Constraint Tunnels (TCTs). In view of an already complex context determined by various product mixes and low volume products, the management of TCTs has become increasingly challenging. To address the difficulty they pose, we have built upon an existing graph based probability estimation approach mixing simulation and list scheduling and improved upon it by introducing an alternate scheduling policy. This policy aims at replicating the ubiquitous dispatching rules existing in the fab and better models the reality. In this article we will explain the original approach and detail the new scheduling policy, then compare them through a comprehensive analysis of industrial instances.

A Simulation-optimization Framework to Solve the Workforce Scheduling Problem in Complex Manufacturing and Logistic Contexts / Ludovica Maccarrone (Sapienza)

We present a new approach to solve the workforce scheduling problem in complex applicative contexts such as manufacturing and logistic processes. We consider systems where several activities require to be carried out by different types of operators, characterized by their skills. We assume the request of such skills is not fixed and may be varied in order to match the time/cost objectives of the organization. In particular, we look at the problem of minimizing the labor cost while meeting deadlines and industrial plans. We employ a set of specific simulators to overcome the intractable complexity of deriving the analytic expressions linking the resources availability to the real activities processing times. All these issues are addressed by a simulation–optimization approach which decomposes the problem into three nested problems: the workforce planning, the activities scheduling and their time estimation by simulation. We illustrate our framework and we retrieve some preliminary results.

Optimizing Production Allocation with Simulation in the Fashion Industry: A Multi-Level Hierarchical Optimization Framework Proposal / Virginia Fani (University of Florence)

Production Planning and Control (PP&C) has been deeply analyzed in the literature, both in general terms and focusing on specific industries, such as the fashion one. This work add a contribution in this field presenting a multi–level hierarchical optimization framework for the fashion industry and an environment composed by focal companies and both exclusive and not–exclusive suppliers. The relevant aspect of this work is related to the peculiarities of this industry, where daily produced quantities differs from the long–term planned ones and where multi–brands suppliers capacity is unknown to focal companies. The proposed framework combine simulation and optimization models based on parameters, decision variables, constraints and Objective Functions (OFs) collected through a literature review. The framework has been developed in a parametrical way, in order to fit the peculiarities of the Fashion Supply Chain (FSC).

Integrating Consumer Adoption Modeling in Renewable Energy Expansion Planning / Anuj Mittal (Iowa State University)

The electricity market in the U.S. is changing rapidly from a utility–scale centralized generation–distribution model to a more distributed and customer–sited energy model. Residential energy consumers in the U.S. have shown increased interest in solar–based electricity at home, resulting in increased adoption of distributed solar on the rooftops of owner–occupied residences (known as rooftop PV). However, increased rooftop PV adoption has led to equity concerns among policymakers, as well as dissatisfaction among utilities due to falling revenues. In this research, a bottom–up simulation–based expansion planning approach through consumer adoption modeling has been proposed to help utilities satisfy consumer demand for distributed solar while also addressing the issues that have arisen from increased rooftop PV adoption.

A Quantile Adaptive Search for Black-box Simulation Optimization on Continuous Domains with Practical Implementations / David Linz (University of Washington)

Due to the use of complex models in simulation, black–box optimization methods have been useful in the field of simulation optimization. Since black–box functions lack exogenous information about the structure of the function,

optimization methods often employ random search to focus sampling inside a domain. This poster describes an optimization framework, Quantile Adaptive Search (QAS), for focusing sampling inside a nested set of quantile level sets on a continuous domain. The poster describes theoretical results regarding the complexity of QAS. In addition, methods for implementing the framework using Probabilistic Branch and Bound and Hit-and-Run are discussed.

Evaluating Static and Adaptive Safety Stock Policies for Robust Pharmaceutical Supply Chains / Rana Azghandi (Northeastern University)

Over the past decade, there has been an epidemic of drug shortages plaguing the U.S. While efforts have been made to address the robustness of pharmaceutical supply chains, shortages persist. Two common drivers of drug shortages are (1) supply disruptions and (2) responses by decision makers throughout the supply chain as they react to these disruptions. To understand and characterize the relationship between these drivers, a systems dynamics model has been developed. Results indicate that, for various decision makers, the best inventory policies, based on Data Envelopment Analysis (DEA), evolve with the type of disruption.

Acquisition Functions for Simultaneous Bayesian Optimisation of Multiple Problems / Michael Pearce (University of Warwick)

Using Gaussian Processes as statistical predictors of expensive objective functions for optimization has gathered much attention over the last two decades. Many acquisition functions that guide the search for data collection have been developed for various optimization cases, including multi-fidelity and multiple objectives. We look at the case where there are multiple optimization problems to be solved simultaneously. One example may be the algorithm selection problem where each use case of an algorithm is a unique optimisation problem, and a user aims to find the optimal setting for each use case based on optimal settings of similar cases. Input uncertainty can be seen as an example where one must use the same settings for all use cases. We propose a variety of acquisition functions for Bayesian optimisation in this general class of optimization problems.

Sustainable Urban Freight Transport: a Simheuristic Approach / Lorena Silvana Reyes-Rubiano (Public University of Navarra)

In modern society, sustainable transportation practices in smart cities are becoming increasingly important for both companies and citizens. This paper addresses a rich extension of the capacitated vehicle routing problem, which considers sustainability indicators and stochastic traveling times. A simheuristic approach integrating Monte Carlo simulation into a multi-start metaheuristic is proposed to solve it. A computational experiment is carried out to illustrate both the problem and the approach.

Measure Valued Differentiation for Stochastic Neural Networks / Thomas Flynn (Graduate Center, City University of New York)

Stochastic neural networks serve as general models useful for machine learning problems. Several models on discrete state spaces have been studied, and their proposed gradient estimation procedures are based on having closed form solutions for the resulting probability distributions. The methods exploit constraints on network connectivity, such as symmetry, or the absence of cycles. Our interest is in the general case of long-term average cost in networks with arbitrary connectivity, where only knowledge of the transition probabilities is available. We propose an algorithm that computes descent directions based on simultaneous perturbation analysis and measure valued differentiation.

A Recommendation System for First-order Nearly Orthogonal-and-balanced (NOAB) Designs / Zachary C. Little (Air Force Institute of Technology / The Perduco Group)

The construction of nearly orthogonal-and-balanced (NOAB) designs is examined for full first-order models in the framework of an algorithm selection problem, allowing for the examination of experimental design performance measures for various design sizes and maximum allowed imbalance settings. Based on a randomly-generated set of large design spaces, performances measures of D-criterion for good parameter estimation as well as estimated maximum unscaled prediction variance (UPV) are largely driven by choice of design size, with specific design space features found to impact the measures. In this multi-objective setting, prediction of design performance within the framework consistently results in designs that perform well over an entire sampled weight space for the multiple performance measures as well as for specific weights.

Using Simulation to Model Clinical Medication Reviews in Community Pharmacies / Kathryn N. Smith (North Carolina State University)

Providing enhanced clinical services to complex patients is one way that community pharmacies are responding to the shift in healthcare to outcomes-based performance over fee-for-services. One enhanced service that is becoming more popular is comprehensive medication reviews (CMRs). CMRs allow pharmacists to educate the patient on how to correctly manage their medications and discover any possible drug therapy problems (DTPs) that could be effecting the patient's adherence and/or health outcomes. Currently, there is not a specific workflow or process for the best way to perform CMRs in a community pharmacy setting. We developed discrete event simulation models to test different CMR workflows in two different pharmacies and determine the effects on patient waiting time and staff utilization.

Sunday 3:30p.m.-5:20p.m.

POSTER / PAVILION

Poster Briefing

Gregory Zacharewicz (University of Bordeaux – IMS)

Applying Lean Principles for an Integrated Process-Based Approach Towards Improved Safety in Building Construction / Jürgen Melzner (Bauhaus-University Weimar)

In the very competitive construction business construction companies looking for methods to improve their processes. The accident rate in the construction industry is the highest rate among all industries. Lean Construction methods offer opportunities to a comprehensive job hazard analysis. The nature of construction projects are separate stages in the planning process. Modern technologies, such as Building Information Modeling, are offering an object-orientated planning approach. This paper solves this problem by applying a lean-process-orientated job hazard analysis based on Building Information Models (BIM). The proposed system generates 4D-visualizations of processes by applying lean construction principals. Thus, safety hazard can interactively detect, accessed and communicated in an early stage in the planning process. The aim of this research is to allocate process risks and hazards, and to implement these in a 3D building model of an actual construction project and simulate different scenarios.

Challenges of Simulating Teamwork in Organizational Scenarios / Lukas Reuter, Jan Ole Berndt, and Ingo J. Timm (Trier University)

Today's workplace is driven by a high amount of available information and hereby the complexity of work processes increases. In this context the project AdaptPRO uses an interdisciplinary approach from business informatics and business psychology to analyze, model and simulate the concept of intentional forgetting by reorganizing roles and processes in an organizational context. Towards the vision of simulating teamwork, this paper proposes an experiment and simulation framework to model and simulate the effects of different role and process configurations in teams. Bringing both of these disciplines together can open up new opportunities for developing and understanding simulation models of human teamwork practices.

Performance Evaluation of MQTT-based Internet of Things Systems / Mohamed Handosa and Denis Gracanin (Virginia Tech) and Hicham Elmongui (Alexandria University)

The Internet of Things (IoT) systems usually use constrained devices with limited computation and communication resources facilitating the use of lightweight communication protocols. Message Queue Telemetry Transport (MQTT) is a lightweight publish-subscribe-based messaging protocol that works on top of the TCP/IP protocol. We present our progress towards building a simulation tool for evaluating the Quality of Service (QoS) in MQTT-based IoT systems. This tool can facilitate the design of IoT systems that need to meet certain QoS requirements.

Comparison of Three Models of Melanoma Growth Based on SPH Solver, Particle Automata (PAM) and Cellular Automata (CA) Paradigms / Bartosz Minch, Filip Koperski, Wojciech Matuła, and Marta Panuszewska (AGH University of Science and Technology)

We compare three discrete computer models of skin cancer proliferation based on smoothed particle dynamics (SPH), particle automata (PAM) and cellular automata (CA). The main contribution of this work are the development of SPH, PAM and CA melanoma models and the attempt to synchronize them in such a way, that the three will produce similar growth scenarios. We have developed two basic models: the first one with tumor penetrating the healthy tissue and the second where tumor evolves on the surface of this tissue (healthy skin). We have confronted our method (SPH) with the PAM and cellular automata models. The biological tissue in SPH method was treated as a viscous fluid – the mechanical interactions are described with Navier–Stokes equations. Main feature that was responsible for tumor growth was concentration of oxygen in tissue. It was governed by modified Fick’s second law of diffusion.

Simulation Results of Optimal Solution for a Multiechelon Inventory System / Jose Francisco Dorado, Paz Perez-Gonzalez, and Jose M. Framinan (University of Seville)

In this paper we present the preliminary results provided by the simulation of inventory management in a supply chain. Real data is taken from a chemical Spanish company with the factory located in the south of Spain, and its supply chain includes distribution centers in different locations in Spain as well as in other European countries. Inventory optimization is applied to the scenario focuses in the main product, and the objective of the simulation is to determine, based on the data of stochastic demands, the cost of inventory derived from the implementation of the replacement point given by the optimization model provided by the literature for multiechelon systems.

Drone Delivery Scheduling Simulations Focusing on Charging Speed, Weight and Battery Capacity: Case of Remote Islands in South Korea / Jinwoo Lim and Hosang Jung (Inha University)

Most countries usually have a logistical dead-zone problem which the delivery demand cannot be fully fulfilled on time via conventional transportation vehicles (i.e. trucks) due to the intrinsic geographical conditions. Demand in either small islands or mountainous regions might be hard to fulfill by logistics providers in comparison with other delivery areas. In this work, we proposed a drone delivery scheduling model and conducted various simulations using it to check the effect of various factors such as recharging speed, drone weight, and battery capacity on the simulation results. To show the feasibility of the proposed model and simulations, we analyzed a real case of remote islands in South Korea.

Simulation Modelling for Making Decision on Clinical Trials Using Acceptability Curve of Cost-Effectiveness and Expected Net Benefits / Ismail Abbas (N/affiliation)

Simulating empirical distributions of costs and health benefits are widely used for making decisions on health interventions. Decisions using acceptability curves (CEAC) are commonly adopted to represents the probability of incremental cost–effectiveness model regarding the Northeast quadrant of joint density of incremental cost and benefits distributions, considering variability within samples. Using an expected net benefits model, we show how to integrate in one curve the distributed points of costs and benefits that fall in Northeast, Southeast, Northwest and Southwest quadrants, considering variability between and within samples. We applied the methods to a clinical trial that evaluates the effects of resonance magnetic image and computerized tomography image in the diagnostic of stroke. Thus, modeling and simulation of expected net benefits allow for drawing an acceptability curve, integrating the four quadrants of joint density of incremental cost and benefits without altering decisions that might be undertaken using the classical acceptability curve approach.

Buffer Overflow Detection in DEVS Simulation Using Canaries / Hae Young Lee (DuDu IT)

This paper addresses buffer overflows (BOFs) in simulations written in the C/C++ language, which could be exploited by attackers to pollute simulation results. The paper then presents a BOF detection method for Discrete Event System Specification, in which canaries placed after buffers are used to detect BOFs. A concept-of-proof of the proposed method that uses a custom pre-

processor has been implemented and shows that BOFs can be detected with minimal modifications.

A Hierarchical Simulation Model for Workload Analysis of Ship Block Erection Process / Huiqiang Shen, Yong-Kuk Jeong, SeungHoon Nam, Youngmin Kim, and Jong-Gye Shin (Seoul National University) and Dong Kun Lee and Daekyun Oh (Mokpo National Maritime University)

In shipbuilding, large blocks are erected and welded in a dry dock to form a ship. Due to finite facilities, limited workspace and huge size of erection blocks, block erection process is typically considered as the bottleneck of the whole shipbuilding process. A complex erection network plan should be established for block erection which indicates the erection orders as well as the schedule of each erection event. Besides, each erection event consists of several sub-processes, which results in high dependency of block erection on erection network. In this research, a hierarchical simulation model is suggested to precisely predict the workload of block erection considering the workload of each sub-processes included. By applying proposed model in erection network simulation, more accurate workload could be calculated.

DEVS Modeling and Simulation Based on Markov Decision Process of Financial Leverage Effect in the EU Development Programs / Emanuele Barbieri, Laurent Capocchi, and Jean-François Santucci (SPE UMR CNRS 6134)

The evaluation of development programs has become essential to verify their success. Indeed, it is necessary to develop prediction tools of the still-planned programs, in a special phase called ex-ante phase, to simulate the effects of fictitious programs or changes in the existing program structure in order to predict the level of leverage of a program from its design stage as well as during the project. The proposed paper consists of the definition of a DEVS-based Markov Decision Process model which, after simulation, may constitute an ex-ante evaluation of a development program. First promising simulation results are presented and seems to confirm the right way of the proposed approach.

Holographic Simulation of Synthetic Battlefield Environments / Matthew B. Haynes, Thomas P. Etheredge, and Matthew C. Rigney (US Army) and Thomas Fronckowiak (Torch Technologies)

Autonomous seeker systems are comprised of imaging sensors coupled with signal-processing algorithms and the on-board processing power to perform engagement, tracking, and terminal guidance operations against a target or threat. Exhaustive testing of these systems is accomplished using simulation environments with high-resolution terrain, vehicle and discrete object models. With the advancement of seeker systems, improved synthetic simulation imagery is required, which drives the need for higher fidelity and higher resolution models. However, development and evaluation of 3D models using standard 2D computer displays is cumbersome and tedious. Further, configuration and evaluation of battlefield engagements – from mission planning, to pre-flight analysis, to post-flight reconstruction – lack simulation tools that provide a collaborative and holistic perspective of the scenario. The developed holographic simulation tool coupled the Microsoft HoloLens Augmented Reality (AR) device provides a platform for evaluating synthetic battlefield environments as well as terrain, vehicle, and object models that comprise them.

Towards Agent-Based Social Simulation as a Method in Literary Studies: Analyzing Creative Processes based on Egodocuments / Daniel S. Lebherz, Fabian Lorig, and Ingo J. Timm (Trier University)

The use of modeling and simulation (M&S) as scientific method is no longer limited to technical disciplines but has also been established in humanities. However, most of the proposed methods originated from statistical and empirically-driven parts of humanities, e.g., social sciences and economics, while M&S is only rarely applied by literary scientists. In this paper, we present an approach to utilize M&S in literary science for facilitating the analysis of an author's creative processes by means of Agent-Based Social Simulation (ABSS). This is especially challenging, when the subject of investigation, i.e., the author, is no longer alive. In this case, all information required for Agent-Based Modeling (ABM) needs to be identified in and extracted from paperwork written by the author (egodocuments) or about the author. In this paper, we outline how ABM and ABSS can be systematically integrated into the research process in literary studies and what challenges arise.

Exploiting Equation-Free Analysis for Multi-Level, Agent-Based Models in Cell Biology / Kai Budde, Tom Warnke, Adelinde M. Uhrmacher, Eric Schätz, and Jens Starke (University of Rostock) and Fiete Haack (Leibniz Institute for Farm Animal Biology)

Multi-level modeling approaches have been successfully applied in systems biology to model complex systems with different levels of organization. They allow for straightforwardly integrating upward and downward causation as well as compartmental dynamics. This makes multi-level models powerful, but also expensive to simulate. Consequently, the effort required for comprehensive simulation studies with complex multi-level models is often prohibitive. One way to decrease the demand for simulations is to apply analysis methods. However, most approaches focus on differential equations models and cannot handle models with stochasticity or dynamical nesting. Among the new approaches that allow for analysis of complex systems is equation-free analysis, which has been applied to perform coarse level bifurcation analysis in various areas. We present the integration of an equation-free method into the simulation language SESSL to analyze bi- or multistability of biochemical models, defined in the multi-level modeling language ML-Rules, and its role in cell fate selection.

Practical Expressiveness of Internal And External Domain-Specific Modeling Languages / Tom Warnke and Adelinde M. Uhrmacher (University of Rostock)

During the long history of modeling and simulation, many answers have been given to the question of how to specify simulation models. Many of these approaches can be perceived as domain-specific modeling languages offering a syntax and a semantics. However, the individual languages are often vastly different. A central distinguishing aspect is the classification as external or internal domain-specific language. External and internal domain-specific languages are characterized by specific trade-offs regarding syntactical flexibility, computational efficiency, and amount of implementation work. We present a case study of alternative approaches to implement domain-specific languages for a small modeling problem in supply chain management. We illustrate the influence of using an external or internal language on different aspects of language performance, in particular the practical expressiveness, which we identify as one of the central properties of modeling languages.

RECAP Simulator: Simulation of Cloud/Edge/Fog Computing Scenarios / James Byrne, Sergej Svorobej, Anna Gourinovitch, Divyaa Manimaran Elango, Paul Liston, PJ Byrne, and Theo Lynn (Dublin City University)

With the increasing trend towards edge and fog computing, the aim of the RECAP simulator is to simulate large scale scenarios in the cloud, fog and edge computing space in order to provide decision and control support for application and data center resource administration. This will be accomplished through the simulation of applications and application subsystems, simulation of infrastructure resources and resource management systems, and experimentation and validation of simulation results. The RECAP simulator and associated models will provide support for understanding and predicting impact on resources, workloads and quality of service (QoS) metrics as well as trade-offs for energy efficiency and cost within cloud, edge and fog computing scenarios, while maintaining the service level agreements (SLAs) of users.

The Application of Actor-Critic Reinforcement Learning for Fab Dispatching Scheduling / Namyong Kim and Hayong Shin (KAIST)

This paper applies Actor-Critic reinforcement learning to control lot dispatching scheduling in reentrant line manufacture model. To minimize the Work-In-Process(WIP) and Cycle Time(CT), the lot dispatching policy is directly optimized through Actor-Critic algorithm. The results show that the optimized dispatching policy yields smaller average WIP and CT than traditional dispatching policy such as Shortest Processing Time, Latest-Step-First-Served, and Least-Work-Next-Queue.

A Note on Simulation for Estimating the Variance of Throughput in Flow Lines With Finite Buffers / Dug Hee Moon and Yang Woo Shin (Changwon National University)

Although analytical approaches and exact solution methods are best for manufacturing system design, it is not easy when the systems become complex. Thus, approximation methods are required and the accuracies of the methods are analyzed by simulation. However, unlike the first order measures such as the mean of throughput, the second order measures such as the variance rate

of throughput is difficult to be converged using simulation study. This paper introduces various phenomena empirically when the variance rate of throughput is estimated by simulation in flow lines.

Multimedia Content Prediction Using the Kalman Filter / Rafael Fernando Diorio and Varese S. Timóteo (University of Campinas (UNICAMP), Faculdade de Tecnologia)

In this work, we explore a prediction method, based on the Kalman filter, for multimedia content delivery purposes. In summary, we predict the multimedia content based on their respective multimedia content identifier, such as by means unique identifiers in the network layer (using the DSCP field in an IP network, for example) or in the application layer (using application content tags, for example). A computational environment, simulating four multimedia services, is used to obtain experimental results. The obtained results show that the proposed method can be used to perform the multimedia content prediction based on their multimedia content identifiers. This approach is important to improve the multimedia content delivery and to increase the user-perceived Quality of Experience (QoE).

Phantom Pareto Systems for Multi-Objective Ranking and Selection / Eric Applegate, Susan Hunter, Guy Feldman, and Raghu Pasupathy (Purdue University)

Consider the context of the Multi-Objective Ranking and Selection (MORS) problem, which is a multi-objective simulation optimization problem on a finite feasible set of systems. Since the Pareto set can only be observed with error, MORS methods often are concerned with the possibility that a misclassification (MC) event occurs, in which a system is misclassified on its status as Pareto or non-Pareto. In two dimensions, phantom Pareto systems have been used to assist in analyzing the probability of an MC event. We construct phantom Pareto systems in d dimensions, describe an algorithm to efficiently locate the phantom Pareto systems in d dimensions, and describe how the phantom Pareto systems can be used in a SCORE framework.

Virtual Terrain Nullification Using Phased Array Antennas / Vinay B. Ramakrishnaiah, Robert F. Kubichek, and Suresh S. Muknahallipatna (University of Wyoming)

The novel approach of Virtual Terrain Leveling (VTL) is proposed that uses phased array antennas to virtually nullify the effects of terrain. VTL acts as a trade-off between the complex antenna design approaches and the simple omni-directional antennas. This method has potential applications in avoiding interference in technologies like 5G, mobile ad hoc networks, and in the deployment of internet of things (IoT) enabled devices. Simulation results are provided to show the distribution of power for different terrains, and to highlight the benefits of using VTL. Simulation results show that VTL tries to increase the antenna gains in the directions of obstacles that increase path loss within a certain threshold. Tests were also conducted with different antenna array geometries with varying number of antennas.

Addressing the Opioid Epidemic: Treatment Capacity Expansion to Reduce Care Disparities for Opioid Addiction Disorders / James Benneyan (Healthcare Systems Engineering Institute) and Hande Musdal, Nikolas Guevara, Madeline King, Grace Jenkins, Andrew Savino, Nicole Nehls, Malcolm Lord, Christine Junod, and Margo Jacobsen (Northeastern University)

The national opioid epidemic continues to worsen as abuse increases outpace treatment access, with many proposing additional state and federal funding for recovery services. To help public health departments plan effectively, we developed coupled models that optimize regional location of treatment facilities across any given state and simulated benefits on access delays, people receiving treatment, overdoses, and associated mortality. We optimized scenarios under expansion investments ranging from 5 to 20 additional treatment facilities across Massachusetts. Results estimate that optimally locating 20 new facilities would yield annual benefits of 18-day reductions in median treatment access delays, 2,332 prevented overdoses, and 237 avoided overdose-related deaths. These models and results can be useful to policy makers and public health officials by informing investment decisions and various tradeoff questions. Ongoing work is incorporating further complexities into the models and exploring the effectiveness of other interventions, such as treatment relapses, capacity pooling, and social distancing.

Underrepresentation of Minorities in Hollywood Films: an Agent Based Modeling Approach to Explanations / Carmen Iasiello (George Mason University)

This paper proposes an examination of the Hollywood labor system as a network using an agent based model (ABM) that creates a co-actor network within a movie labor market based on preferential attachment and compares the findings with 50 co-production ego networks during the 2015 movie cycle. Using ABM, the tested hypothesis is that slight individual preference for racial and ethnic similarity within one's own network at the microlevel sufficiently explains the phenomena of Hollywood racial minority underrepresentation at the macrolevel. Using regression analysis of the real-world co-actor networks the tested hypothesis is that minority status affects one's position within the network of successful actors. In both cases, the hypotheses are insufficient to explain the phenomena and this paper proposes further exploration into causes of opportunity loss in accessing the labor market merit further study.

Automatic and Dynamic Grounding Method Based on Sensor Data for Agent-Based Simulation / Shohei Yamane, Kotaro Otori, and Hiroaki Yamada (Fujitsu Laboratories Ltd.)

Congestion prediction is one of important issues in large-scale facilities in order to improve user satisfaction. Agent-based simulation (ABS) is a promising way to reproduce congestion situations and to evaluate the effectiveness of various types of policies for congestion avoidance based on individual behavioral model. Real-world grounding for determining model parameters plays important role to build valid ABS for a specific facility. However, to use ABS continuously for daily decision, parameters should be updated because user characteristics of the facility changes daily or longer term. This study provides a novel grounding method that can automatically and dynamically estimate the parameters of a human behavioral model based on sensor data at a certain interval. To evaluate the method, we conduct simulation experiments using an agent based model to analyze congestion situation in a building. The result with the method can perform congestion prediction with higher accuracy as compared with a conventional method.

Simulation Based Decision Support for Contact Centers / Paul Liston, James Byrne, Orla Keogh, and PJ Byrne (Dublin City University) and Joe Bourke and Karl Jones (IT Solutions Limited)

Call centers are now experiencing a period of rapid evolution, as new communication technologies have become available, customer expectations have increased, and the strategic importance of customer experience has been recognized. While traditional single-channel call centers proved complex to analyze (the challenges and successes of modelling call centers have been widely published), the modern multi-channel connection centers with concurrent conversations and new technologies bring greater levels of complexity to managerial decision making. This paper presents the output of a current research project exploring simulation based contact center analysis, and suggests how advancing beyond traditional Erlang-C based calculators benefits organizations that need to understand and quantify the impact of change in their customer support business.

Airline Disruption Recovery Using Symbiotic Simulation and Multi-fidelity Modelling / Bhakti Stephan Onggo (Trinity College Dublin)

The airlines industry is prone to disruption due to various causes. Whilst an airline may not be able to control the causes of disruption, it can reduce the impact of a disruptive event, such as a mechanical failure, with its response by revising the schedule. Potential actions include swapping aircraft, delaying flights and cancellations. This poster will present our research into how symbiotic simulation could potentially be used to improve the response to a disruptive event by evaluating potential revised schedules. Due to the large solution space, exhaustive searches are infeasible. Our research is investigating the use of multi-fidelity models to help guide the search of the optimisation algorithm, leading to good solutions being generated within the time constraints of disruption management.

Projecting the Impact of Pre-Exposure Prophylaxis for HIV Prevention in the Context of Gonorrhea and Chlamydia Infection / Parastu Kasaie (Johns Hopkins) and David W. Dowdy and Lucas Buyon (Johns Hopkins University)

Pre-exposure prophylaxis (PrEP) is recommended for preventing HIV infection among individuals at high risk, including men who have sex with men (MSM).

The synergy of HIV and other sexually transmitted infections (STIs) including gonorrhea (NG) and chlamydia (CT) can provide a unique opportunity to target populations at highest risk for HIV infection. However, the population-level impact of such programs at current (and improved) levels of STI screening remains uncertain. Applying an agent-based simulation of HIV and NG/CT infection, we explored the impact of NG/CT-targeted PrEP among MSM in Baltimore City. Our results suggest that targeting MSM infected with NG/CT can be an effective means of PrEP delivery. If high levels of STI screening can be achieved at the community level, NG/CT diagnosis may be an important and efficient entry point for PrEP evaluation and delivery; expanding NG/CT screening in conjunction with PrEP can augment this impact even further.

Parallel in Time Solution of Ordinary Differential Equation for Near Real-Time Transient Stability Analysis / Sumathi Lakshmiranganatha and Suresh S. Muknahallipatna (University of Wyoming)

Power system stability is one of the major concerns raised as the power grid is modernized with the recent technological advancements to achieve a smarter and more resilient grid. With the increase in the size of the grid, the requirement of maintaining synchronism among the various components and controllability is a major challenge. Recent research in time-parallel algorithms has paved enormous opportunities for real-time power system analysis. Transient Stability Analysis (TSA) of a power grid involves solving a large set of time-dependent Ordinary Differential Equations (ODEs) and algebraic equations which makes it infeasible for a real-time solution. This poster discusses an approach for feasible near real-time solution of ODEs using Parareal Algorithm (PA). PA implementation using general purpose graphical processing units (GPGPU) based high-performance computing (HPC) is demonstrated for a Single Machine Infinite Bus (SMIB) power system model achieving a speedup of 73x substantiates the potential for near real-time TSA.

Toward Hybrid Simulations for Care Demand Forecasting / Jan Ole Berndt, Ingo J. Timm, Joscha Krause, and Ralf Münnich (Trier University)

Demographic change leads to an increasing demand of health care services. To provide the required services at the right locations, methods for forecasting future demands are needed. The goal of this research is to combine two different simulation techniques to forecast future care service demands. On the one hand, forecasts of demographic change are required. On the other hand, a plausible forecast must account for individual decisions for specific types of care. Thus, the paper outlines an approach to combine statistical micro-simulation of demographic change with agent-based social simulation of individual interactions.

Adaptive Monte Carlo Sampling Gradient Method For Optimization / Hui Tan (Purdue University)

We present a stochastic gradient descent algorithm with adaptive sampling for the unconstrained optimization problem where the function or the gradient is not directly accessible. We show that the algorithm exhibits global convergence and discuss the work complexity with different choices of predetermined function in the sampling rule.

Estimating Main and Interaction Effects of a Multi-Component Randomized Control Trial via Simulation Meta-Heuristics / James Bennehan, Demetri Lemonias, and Iulian Ilies (Northeastern University)

Randomized control trials often are conducted on multi-component interventions in all-or-none manners for pragmatic, logistic, or statistical purposes, allowing researchers the ability only to estimate the over-all effect of the intervention en masse. We propose a simulation-based approach in parallel to estimate main and interaction effect sizes of intervention sub-components via meta-heuristic parameter search leveraging intra-trial longitudinal input, context, and output data. This approach is illustrated on a recent application to an integrated suite of three healthcare information technology patient safety tools tested in a multi-unit staggered cluster crossover RCT design intended to reduce falls, infections and other adverse events as a clinical unit varies in occupancy, staffing, patient risk, care team composition, and tool adherence. A high fidelity simulation of individual and combined use of these tools was developed, validated, and used to estimate sets of effect sizes that maximally reproduce observed data. Computational results and implications are discussed.

Analyzing the Korean Labor Market of the Elderly People Using Agent-Based Modeling / Chun-Hee Lee, Jang Won Bae, Joonyoung Jung, and Euihyun Paik (ETRI)

The aging of population gives rise to many social problems. One of them is the saturation of the labor market of the elderly people. To stabilize the labor market of the elderly, the government should understand the market in depth and make an good policy. In this paper, using agent-based modeling, we simulate the Korean labor market of the elderly people to observe how the employment rate changes in various situations.

Reproducible Network Research with a High-Fidelity Software-Defined Network Testbed / Xiaoliang Wu, Qi Yang, Xin Liu, and Dong Jin (Illinois Institute of Technology) and Cheol Won Lee (National Security Research Institute)

The transformation of innovative research ideas to production systems is highly dependent on the capability of performing realistic and reproducible network experiments. In this work, we present a hybrid testbed to advocate high fidelity and reproducible networking experiments, which consists of network emulators, a distributed control environment, physical switches, and end-hosts. The testbed (1) offers functional fidelity through unmodified code execution on an emulated network, (2) supports large-scale network experiments using lightweight OS-level virtualization techniques and capable of running across distributed physical machines, (3) provides the topology flexibility, and (4) enhances the repeatability and reproducibility of network experiments. We validate the fidelity of our hybrid testbed through extensive experiments under different network conditions and compare the results with the benchmark data collected on physical devices. We also use the testbed to reproduce key results from published network experiments, such as Hedera, a scalable and adaptive network traffic flow scheduling system.

Sunday 4:00p.m.-5:15p.m.

PHD COLLOQUIUM / TRAILS

Ph.D. Colloquium Presentations II

Emily Lada (SAS Institute Inc.)

Discrete Event Simulation Scenario Testing of Schematic Layouts in an Emergency Department Expansion Project / Jennifer Lather (The Pennsylvania State University)

Emergency department (ED) expansion and redesign is a complex design task which must take into account many operational processes (current and proposed) as well a projected changes in the system, e.g., patient volume. Discrete event simulation (DES) is a tool to aid the decision making process by simulating these processes; however, it's typically used in the operations or early design stages before many decisions are made about layout, capacity, and new processes. Later in the design process, the use of simulation can provide an avenue for what-if scenario testing of layout and programmatic changes. This presentation presents an initial discrete event simulation analysis of various layout options during the schematic design stage of an ED expansion project and provides a brief overview of future research directions evaluating decision making using discrete event simulation and visualization simulation.

An Architecture to Simulate Diffusion Processes in Multiplex Dynamic Networks / Cristina Ruiz-Martín (Carleton University)

Dynamic Complex Systems have been analyzed using diffusion processes in multiplex networks, nevertheless, there are no well-established modeling and simulation (M&S) mechanisms for these applications. We present an architecture based on Network Theory, Agent Based Modeling and Discrete Event System Specifications (DEVS) to simulate diffusion processes in dynamic multiplex networks. The proposed architecture provides rigor and formalism to the study of diffusion processes in multiplex networks.

Using Simulation Optimization for Interdependent Operations in Health Centers / Vahab Vahdat (Northeastern University)

Many patients require multiple services provided by different departments and facilities during one visit to a health center or hospital. These multiple services provided to common patients define interdependencies among departments

within a hospital, in which the operation and efficiency of one department may impact the other interrelated departments. In order to minimize the total patient length of stay for those with multiple services, a simulation–optimization framework is constructed. The day–to–day operation of each department is simulated using discrete–event simulation modeling. At the beginning of each iteration, an optimization model for each node defines the patient and provider schedules and resource allocation for each hour of the day. The simulation results, inflows, and outflows of each department are used to inform the next day optimization model. This iterative procedure continues, until the performance gap become minimal.

A Computational Model of Action Potential in the Mouse Detrusor Smooth Muscle Cell / Chitaranjan Mahapatra (Indian Institute of Technology Bombay)

Urinary incontinence is associated with enhanced spontaneous phasic contractions of the detrusor smooth muscle (DSM). It is suggested that the spontaneously evoked action potentials (sAPs) in DSM cells initiate and modulate the contractions. In order to further our understanding of the underlying ionic mechanisms in sAP generation, we present here a biophysically detailed computational model of a single DSM cell. We constructed mathematical models for nine ion channels found in DSM cells based on published experimental data. After incorporating all ion channels, our DSM model is capable of reproducing experimentally recorded spike–type sAPs of varying configurations. To date, a biophysically detailed computational model does not exist for DSM cells. Our model, constrained heavily by physiological data, provides a powerful tool to investigate the ionic mechanisms underlying the genesis of DSM electrical activity, which can further shed light on urinary bladder function and dysfunction.

Ontology-Based Modeling Framework to Generate Federation Object Model in the Supply Chain Domain / Juan Leonardo Sarli (CONICET UTN INGAR)

Federation Object Model (FOM) guarantees interoperability among systems in High Level Architecture simulations. The FOM is a domain–specific document that requires an agreement among participants of simulation. This work presents a modeling framework based on an ontology network to conceptualize supply chain and simulation domains. This framework is the foundation of a software tool for a semiautomatic generation of a FOM. The ontology network formalizes a supply chain (SC) operations reference model to depict, in a common terminology, a SC. Besides, through the execution of derived axioms, integrity axioms and rules in the ontology network the composition of the SC model is validated, taking into account the syntactic and semantic correctness of the FOM.

Toward Precise Semantics of Actions / Abdurrahman Alshareef (ASU)

Action is the fundamental unit of behavioral specification in models. We propose the use of Discrete Event System Specification (the DEVS formalism) to specify the semantics of actions. Then, coupling is used to form different kinds of behavioral models. The statecharts and activities are two different approaches by which the system behavior can be described. Actions are at the core of these two approaches and therefore their specifications can collectively serve as a significant part of the overall behavior alongside with behavior of other parts such as control. Thus, we propose an approach introducing the concepts of time and state as defined in DEVS for actions; these serve as an abstraction for modeling a wide range of systems.

Tumor Simulation by Using Supermodeling – An Example of a New Concept of Data Assimilation in Modeling of Complex Systems / Adrian Khusek (AGH University of Science and Technology)

We introduce a new concept of data assimilation in simulation of complex systems, such as tumor proliferation, by using supermodeling paradigm. We demonstrate that the integration of the supermodel with real data involves learning only a limited number of sub–model coupling coefficients instead of a lot of parameters of a single, usually complex and overfitted cancer model.

A Devs Based Modeling Architecture of Electrical Power Systems / Ange-Lionel Toba (Old Dominion University)

Recurrent energy planning issues cited in the literature are (1) the growth in demand for energy, (2) the challenge of diversity in energy supply and (3) the concern about energy security and environmental constraints, particularly the challenge of climate change (Safi et al. 2012). Decision–makers in the power system infrastructure domain have to deal with physical and financial constraints as well as uncertainties related to these issues (Van Dam 2009). In this

research, Spark!, an energy system simulation model developed on a DEVS (Discrete Event System Specification) platform, offers a realistic representation of large scale power grids. The model captures the intermittence of renewables, constraints of conventional generation resources, geographical and climate information, the transmission capacities, and offers flexible time resolution.

Simulating Ddos Attacks on the us Fiber-optics Internet Infrastructure / Sumeet Kumar (CMU)

In November of 2017, a DDoS attack tried to bring down the Internet connectivity of the African nation of Liberia. It was reported that the attacks consumed over 500 Gbps bandwidth of the Africa Coast to Europe (ACE) fiber cables that provide the Internet to Europe and Africa. The incident highlights the vulnerabilities that exist in the Internet infrastructure. We need a simulation testbed that can reflect the complexity of the Internet, yet allows to swiftly test attacks, providing insights that can apply to real-world attack scenarios. In this research, we try to identify such vulnerable points using a simulation. This work summarizes our original work on 'Simulating DDoS Attacks on the US Fiber-Optics Internet Infrastructure' accepted as a full paper at the Winter Simulation Conference, 2017.

Combined DEVS Multiresolution Simulation and Model Checking / Soroosh Gholami (Arizona State University)

We propose using Multiresolution Modeling (MRM) for system level design of networked software systems. This methodology aids in creating a family of models at different levels of complexity. We have developed an MRM framework to support hierarchical modeling as exemplified for Network-on-Chip (NoC) systems, as exemplar of network systems, with support for both validation and verification. Throughout the design phase, fine-grain models are created using their coarse-grain counterparts. Each model can be validated using discrete-event simulation and verified using model checking. We propose Constrained-DEVS, a variant of the Discrete Event System Specification (DEVS) formalism, which supports model checking in addition to DEVS's discrete-event simulation capability. Appropriate execution protocols for mixed V&V (validation and verification) are proposed. This leads to an MRM framework enabling both simulation and model checking. This framework is realized through extending the DEVS-Suite simulator and its applicability demonstrated for exemplar NoC models.

An Analysis Model to Evaluate Web Applications Quality Using a Discrete-Event Simulation Approach / María Julia Blas (INGAR (UTN-CONICET))

The architectural design can be considered the earliest specification of any software. When the architectural components are used to describe a simulation model, the architecture can be used as a vehicle to estimate the behavior of the final product. In this paper, an analysis model to evaluate web applications quality is proposed. The approach mix an ontological perspective to understand quality properties and an adaptation of Discrete Event System Specification (DEVS) formalism to develop the set of simulation models required to represent the software architecture.

Detection of Emergent Behaviors in System of Dynamical Systems Using Similitude Theory / Shweta Singh (Northeastern University)

The existence of emergent properties, desirable or undesirable, makes a system harder to analyze and design, and requires a formal approach for detecting and reasoning about its causes and nature. The research effort presented in this extended abstract focuses on exploring emergent behaviors in a multi-agent dynamical system with the intent of reduction in complexity of detection of such unexpected behaviors. Our approach relies on the theory of similitude, where the main idea is that similar behaviors occur when the values of the system variables are in a specific relation. These relations, captured using dimensionless quantities, define a hypersurface in the space spanned over the system variables, which in turn can be used to measure the distance to potential undesirable behaviors. We use similitude theory to detect undesirable emergent behaviors in swarms of UAVs (Unmanned Aerial Vehicles), treated as a complex dynamical system. This work is part of ongoing research.

BIM-based Building Permit Procedures Using Decision Making Methods / Judith Ponnewitz (Bauhaus-Universität Weimar)

The Building Information Modeling (BIM) methodology deals with the digita-

lization of the whole construction process and the collaboration of all involved people. In German construction supervision authorities, a conventional and decentralized working with paper media is used and is related to challenges in processing times and communication. Several scientific approaches provide opportunities to check a variety criteria automatically. To define basis for an international standard all process criteria and parameters should be identified in detail. An empirical study to analyze the high potential of BIM in building supervision authorities is proposed. This approach suggests the scientific design of an empirical study and first results. The variety of how to practice decision procedures in building authorities should be carried out. The analyzation should be shown as a descriptive model based on decision analysis methods.

Sunday 5:30p.m.-7:00p.m.

POSTER / FOYER

Joint PhD Colloquium and Poster Session

PHD COLLOQUIUM / FOYER

Joint PhD Colloquium and Poster Session

Monday 8:00a.m.-9:30a.m.

KEYNOTE / SUMMERLIN BALLROOM

50th Anniversary Keynote: Barry L. Nelson

Ernie Page (MITRE Corporation)

WSC 2067: What Are The Chances? / Barry L. Nelson (Northwestern University)

At the November 1967 “Conference on the Applications of Simulation Using GPSS” it seems unlikely that anyone was wondering if the conference would still be occupying a big hotel in 2017. Conferences persist for many reasons, but a technical conference like WSC has to remain relevant to users, vendors, researchers and consumers (not just hotels) to survive. If our kind of simulation vanished, then so (eventually) would WSC. What is required for simulation to “remain relevant” for the next 50 years? Without fear of having to answer for my crimes in 2067, I boldly speculate on what **SHOULD** matter for the next 10–20 years, if not the next 50, with a focus on our strength: dealing with uncertainty.

BARRY L. NELSON is the Walter P. Murphy Professor of the Department of Industrial Engineering and Management Sciences at Northwestern University and a Distinguished Visiting Scholar at Lancaster University in England. His research focus is on the design and analysis of computer simulation experiments on models of discrete–event, stochastic systems, including methodology for simulation optimization, quantifying and reducing model risk, variance reduction, output analysis, metamodeling and multivariate input modeling. His application areas are manufacturing, services, financial engineering and transportation. He has published numerous papers and three books, including *Foundations and Methods of Stochastic Simulation: A First Course* (Springer, 2013). Nelson is a Fellow of INFORMS and IIE. In 2006, 2013 and 2015 he received the Outstanding Simulation Publication Award from the INFORMS Simulation Society, and in 2009, 2011 and 2015 he was awarded the Best Paper–Operations Award from IIE Transactions. His teaching has been acknowledged by a Northwestern University Alumni Association Excellence in Teaching Award, a McCormick School of Engineering & Applied Science Teacher of the Year Award, and the IIE Operations Research Division Award for Excellence in the Teaching of Operations Research. Further information, including a complete CV, can be found at <http://www.iems.northwestern.edu/~nelsonb/>. His email address is nelsonb@northwestern.edu.

Monday 10:00a.m.-11:30a.m.

HISTORY OF SIMULATION / TRAILS

History of the Winter Simulation Conference, I

Russell R. Barton (Pennsylvania State University)

History of the Winter Simulation Conference: Overview and Notable Facts and Figures / Dave Goldsman and Mariana de Almeida Costa (Georgia Institute of Technology), Paul Goldsman (self–employed), and James R. Wilson (North Carolina State University)

The Winter Simulation Conference (WSC) is the leading international forum for disseminating recent advances in computer simulation. WSC also provides an unmatched occasion for interactions between simulation practitioners, researchers, and vendors working in all disciplines and in the academic, governmental, industrial, and military sectors. In this paper we discuss key aspects of WSC’s evolution over the past fifty years. The discussion is based on our examination of all WSC Proceedings papers published between 1968 and 2016, which collectively document much of the history of simulation and WSC. We gather and summarize interesting facts and figures about WSC authors and their Proceedings papers so as to gain insights into conference dynamics and the interconnections between notable authors and between highly cited papers. We extract relevant information from the Web of Science, Scopus, and Google Scholar databases; and we present network visualizations of the interconnections between authors and between papers.

History of the Winter Simulation Conference: Origins and Early Years (1967–1974) / Thomas J. Schriber (Ross School of Business, University of Michigan) and Julian Reitman, Arnold Ockene, and Harold G. Hixson (Not Applicable)

This paper discusses the Origins and Early Years (1967–1974) of the Winter Simulation Conferences. Summary information is given for each of the conferences in that interval, with expanded discussion included for the 1967, 1968, and 1969 formative conferences. The last of these Early Years conferences leads into the sequential paper in this History of the Winter Simulation Conference session, which deals with the Winter Simulation Conference Renaissance Period (1975–1982).

History of the Winter Simulation Conference: Renaissance Period (1975 – 1982) / Robert G. Sargent (Syracuse University), Paul Roth (pr productions), and Thomas J. Schriber (The University of Michigan)

This paper discusses the history of the Winter Simulation Conference (WSC) during the period 1975–1982. This includes the collapse of the WSC in 1975, the rebirth of WSC in 1976, and the subsequent annual conferences and other significant WSC events for the period of 1976 through 1982. This was a period of great change for the WSC, with an emphasis on developing procedures to insure the long-term continuity and success of the conference.

INTRODUCTORY TUTORIALS / RED ROCK G

The Basics of Simulation

Christine Currie (University of Southampton)

The Basics of Simulation / K. Preston White (University of Virginia) and Ricki G. Ingalls (Diamond Head Associates)

Simulation is experimentation with a model. The behavior of the model imitates some salient aspect of the behavior of the system under study and the user experiments with the model to infer this behavior. This general framework has proven a powerful adjunct to learning, problem solving, and design. In this tutorial, we focus principally on discrete-event simulation—its underlying concepts, structure, and application.

ADVANCED TUTORIALS / VERANDA C

Toward Reliable Validation of HPC Interconnect Simulation Models

Christopher D. Carothers (Rensselaer Polytechnic Institute)

Toward Reliable Validation of HPC Interconnect Simulation Models / Misbah Mubarak (Argonne National Laboratory), Nikhil Jain (Lawrence Livermore National Laboratory), Jens Domke (Tokyo Institute of Technology), Noah Wolfe and Caitlin Ross (Rensselaer Polytechnic Institute), Kelvin Li (University of California at Davis), Abhinav Bhatele (Lawrence Livermore National Laboratory), Christopher D. Carothers (Rensselaer Polytechnic Institute), Kwan-Liu Ma (University of California at Davis), and Robert B. Ross (Argonne National Laboratory)

While the high performance computing (HPC) community is increasingly relying on the use of simulation to co-design and optimize HPC interconnects, the community lacks a coherent set of practices that should be followed when validating these simulations. Validating simulations of the HPC interconnect is a multi-phase process starting from the selection of representative communication patterns, then accurately configuring the simulated network, followed by carefully designing the set of experiments, and finally documenting the outcome for reproducibility. In this paper, we present a set of recommended practices that should be followed for each of these phases during the validation process. The end result, while complying with these guidelines, should be a validated interconnect simulation that is able to make accurate performance predictions for the simulated HPC interconnect network and that convinces the community about the correctness of the model.

MODELING METHODOLOGY / RED ROCK I

Modeling Formalisms

Adeline Uhrmacher (University of Rostock)

Towards a Universal Formalism for Modeling and Simulation / Fernando Barros (University of Coimbra)

The representation of hybrid systems has shown to be one of the greatest challenges in Modeling & Simulation. While discrete event systems can be represented without error, continuous models rely on approximations based on numerical methods. Given the large variety of these solvers a unified representation has been elusive due to the lack of an universal formalism that can describe all numerical methods and to provide their seamless integration. In this paper we propose the Hybrid Flow System Specification (HyFlow) as a unifying representation for different families of numerical integrators for solving ordinary differential equations (ODEs). HyFlow combines the conventional discrete event representation with a novel representation based on sampling and the support for dense outputs to describe modular and hierarchical hybrid systems. We demonstrate that HyFlow can describe 1st-order, geometric (2nd-order), and exponential integrators. Additionally, since they share the same underlying HyFlow representation, these solvers can be seamlessly integrated.

An Abstract State Machine Semantics for Discrete Event Simulation / Gerd Wagner (Brandenburg University of Technology)

We define an operational (transition system) semantics for the two most basic forms of Discrete Event Simulation (DES): event-based simulation (without objects) and object-event simulation. We show that under our operational semantics, DES models correspond to a certain form of abstract state machines (ASMs) such that the Future Event List (FEL) is part of the transition system state and the transition function is based on event routines. Unlike other formalisms proposed for DES (such as Petri Nets or DEVS), our ASM semantics takes all basic DES concepts (like event types and the FEL) into consideration and allows for expressive transition system states representing the objects, properties, relations and functions of the evolving possible worlds of a simulation run. As a direct formal semantics of DES, it provides a basis for comparing, and explaining design choices in, different DES approaches.

Routing Structure Over Discrete Event System Specification: A DEVS Adaptation To Develop Smart Routing In Simulation Models / Maria Julia Blas, Silvio Gonnet, and Horacio P. Leone (INGAR (UTN-CONICET))

The Discrete Event System Specification (DEVS) formalism has become an engine for advances in modeling and simulation technology. Many extensions of the DEVS formalism have been developed across the years in order to solve different types of situations. However, when the acceptance of input events and the generation of output events are related to model capabilities, the current formalisms come up with complex modeling solutions. This paper presents a new simulation formalism called Routed DEVS (RDEVS) in which routing information is used to manage directed events. The behavior supported by the new formalism is useful to create simulation models of web application architectures. However, it could also be applied to other contexts. The RDEVS formalism is based on DEVS and is closure under coupling (i.e. models can be built hierarchically). The formal specification of RDEVS formalism and a brief description of its framework implementation are presented in this work.

AGENT-BASED SIMULATION / RED ROCK H

Epidemics Modeling and Control

Parastu Kasaie (Johns Hopkins University)

Hybrid Agent-Based Modeling of Zika in the United States / Chris J. Kuhlman, Yihui Ren, Bryan Lewis, and James Schlitt (Virginia Tech)

Vector-borne infectious diseases present computational modelers with a unique challenge: finding the right balance between model fidelity and simulation costs. In this work, we introduce a hybrid agent-based model that achieves a balance that readily scales to problem sizes of millions of human agents and mosquitoes. Macroscopically, our model results agree with those from a low-cost compartmental model; microscopically, like agent-based models, it provides details at the individual level. We apply this model to a synthetic human population of 1.2 million individuals from Miami, Florida in the United States to model the Zika

outbreak in the Fall of 2016. We identify two high-risk locations within this region, a detail which cannot be revealed by traditional compartmental models. The principles-based mathematical derivation of the hybrid agent-based model can be adapted to other scenarios facing similar tradeoffs.

Exploring the Epidemiological Impact of Universal Access to Rapid Tuberculosis Diagnosis Using Agent-based Simulation / Parastu Kasaie, Hojoon Sohn, and Emily Kendall (Johns Hopkins Bloomberg School of Public Health); Gabriela Gomez and Anna Vassall (London School of Hygiene and Tropical Medicine); Madhukar Pai (McGill University); and David Dowdy (Johns Hopkins Bloomberg School of Public Health)

Many high-burden countries have committed to providing universal access to rapid diagnosis of tuberculosis (TB), but the corresponding impact on population-wide incidence is unknown. We designed an agent-based simulation of drug-susceptible (DS) and drug-resistant (DR) TB in a representative Indian setting and compared the impact of Xpert testing via a decentralized (Xpert available at each local-population) versus centralized (Xpert available at the district-level serving multiple local-populations) strategy. Decentralized testing resulted in a 36% reduction in DR-TB incidence at 10 years compared to no Xpert. Depending on assumptions regarding pre-treatment loss to follow-up (ranging from 5 to 50%), the impact of centralized testing ranged from a 35% to 22% reduction in DR-TB incidence. Implementation of Xpert by either approach had a negligible impact (<5%) on DS-TB incidence. Decisions regarding choice of centralized vs. decentralized Xpert will heavily depend on operational aspects of centralized Xpert and loss to follow-up.

HYBRID SIMULATION / HILLS

Simulation & Analytics - 1

Navonil Mustafee (University of Exeter)

A Hybrid Process-Mining Approach for Simulation Modeling / Waleed Abohamad, Ahmed Ramy, and Amr Arisha (Dublin Institute of Technology)

This paper presents a hybrid Modeling and Simulation framework to address business process challenges. The framework has integrated process mining techniques in the conceptual modeling phase to support developing simulation models that are unbiased and close reflection of reality in a timely manner. The hybrid approach overcomes the pitfalls of traditional conceptual modeling by using process mining techniques to discover valuable process knowledge from the analysis of event logs. The proposed hybrid framework has been applied to an Emergency Department (ED) in order to identify performance bottlenecks and explore improvement strategies in an attempt to meet national performance targets. A large number of unique process flows (i.e. patient pathways) within the ED were uncovered and deviations from process guidelines were accurately identified. Results show that unblocking of ED outflows have a significant impact on patients length of stay (over 80% improvement) rather than increasing the ED physical capacity.

Learning about Systems Using Machine Learning: Towards More Data-driven Feedback Loops / Mahmoud Elbattah and Owen Molloy (NUI Galway)

Machine Learning (ML) has demonstrated great potentials for constructing new knowledge, or improving already established knowledge. Reflecting this trend, the paper lends support to the discussion of why and how should ML support the practice of modeling and simulation? Subsequently, the study goes through a use case in relation to healthcare, which aims to provide a practical perspective for integrating simulation models with data-driven insights learned by ML models. Through a realistic scenario, we utilise ML clustering in order to learn about the system's structure and behaviour under study. The insights gained by the clustering model are then utilised to build a System Dynamics model. Recognizing its current limitations, the study is believed to serve as a kernel towards promoting further integration between simulation modeling and ML.

A Hybrid Approach For Building Models And Simulations For Smart Cities: Expert Knowledge And Low Dimensionality / Elhabib Moustaid and Sebastiaan Meijer (KTH)

In face of high urbanization and increasing mobility, models and simulations are used to find answers for urban planning problems. However, simulations face criticism for over-simplifying complex reality, having models disconnected from the context of their use or excluding policy-makers from the building of models.

Smart city approaches did not overcome that reality even if they relied more and more on microscopic models, together with data available through technology. This article describes a hybrid approach combining the expert knowledge on the city and its limits in terms of data, with models having the right dimensionality to provide policy-makers and urban managers with the necessary information for understanding and managing the city. This approach has been applied in Venice, but it describes in more general terms a way of bridging the world of theoretically sound models with their potential use.

ANALYSIS METHODOLOGY / VERANDA B

Simulation Analysis

James R. Thompson (MITRE Corporation)

Simulation-based Predictive Analytics for Dynamic Queueing Systems / Huiyin Ouyang (The University of Hong Kong) and Barry L. Nelson (Northwestern University)

Simulation and simulation optimization have primarily been used for static system design problems based on long-run average performance measures. Control or policy-based optimization has been a weakness, because it requires a way to predict future behavior based on current state and time information. This work is a first step in that direction with a focus on congestion measures for queueing systems. The idea is to fit predictive models to dynamic sample paths of the system state from a detailed simulation. We propose a two-step method to dynamically predict the probability of the system state belongs to a certain subset and test the performance of this method on two examples.

Comparative Analysis of Metamodeling Techniques Based on an Agent-Based Supply Chain Model / Mert Edali and Gonenc Yucel (Bogazici University)

Agent-based models comprise interacting autonomous entities, and generate both individual and emergent system-level outputs. These models generally have a large set of free parameters, whose impact on output needs to be explored. Considering also the need for replication due to stochasticity, a proper analysis requires a very large set of simulation runs. Therefore, obtaining a simpler representation of a simulation model (e.g., metamodel) can prove useful. We primarily focus on the potential utilization of various metamodeling approaches, namely Decision Trees, Random Forests, k-Nearest Neighbor Regression, and Support Vector Regression in predicting the two different types of outputs of an agent-based model. Results show that system-level outputs are predicted with higher accuracy compared to individual-level outputs under equal sample sizes. Although there is no single metamodeling technique performing best in all cases, we observe that support vector regression is more robust to the increase in the dimension of the problem.

Deep Gaussian Process Metamodeling Of Sequentially Sampled Non-Stationary Response Surfaces / Vincent Dutordoir and Ivo Couckuyt (Ghent University)

Simulations are often used for the design of complex systems as they allow to explore the design space without the need to build several prototypes. Over the years, the simulation accuracy, as well as the associated computational cost has increased significantly, limiting the overall number of simulations during the design process. Therefore, metamodeling aims to approximate the simulation response with a cheap-to-evaluate mathematical approximation, learned from a limited set of simulator evaluations. Kernel-based methods using stationary kernels are nowadays widely used. However, using stationary kernels for non-stationary responses can be inappropriate and result in poor models when combined with sequential design. We present the application of a novel kernel-based technique, known as Deep Gaussian Processes, which is better able to cope with these difficulties. We evaluate the method for non-stationary regression on a series of real-world problems, showing that it outperforms the standard Gaussian Processes with stationary kernels.

SIMULATION OPTIMIZATION / PAVILION

Simulation Optimization Applications

Dashi I. Singham (Naval Postgraduate School)

Sample Average Approximations for the Continuous Type Principal-Agent Problem: An Example / Dashi I. Singham (Naval Postgraduate School) and Wenbo Cai (New Jersey Institute of Technology)

Principal–agent problems study contracts for goods or services that a principal (seller) should offer an agent (buyer). The goal is for the principal to optimize the quantity and price in the contract offered to an agent with uncertain demand, where the principal has estimated a distribution for the agent’s demand. The agent’s demand distribution can be discrete or continuous. A deterministic optimization solution to the discrete distribution problem delivers a contract with price and quantity options targeted towards each possible demand realization. When the demand distribution is continuous, the optimal contract becomes a continuous function of the demand space. This paper introduces a sample average approximation to the continuous distribution problem using methods for solving the discrete distribution problem. We explore using numerical results an example motivated by carbon capture and storage systems.

A Simulation-Based Quality Variance Control System for the Environment-Sensitive Process Manufacturing Industry / Lin Tang, Miao He, Xunan Zhang, Yutao Ba, and Changrui Ren (IBM Research - China)

Optimizing the process parameters with respect to the future environmental conditions is an immediate challenge for environment–sensitive process manufacturing industry to achieve more consistent production quality. In this paper, we propose a simulation–based quality variance control system consisted of three core components: an indoor environment calibration module, a quality prediction module and a simulation engine. We then demonstrate the use of this system by analyzing a typical manufacturing process consisted of four sub–processes. The studies show that the proposed system can achieve better performances by integrating future indoor environment calibration module than that of without such module. In addition, the simulation–based method can provide more acceptable outcome which outperforms the collaborative filtering algorithm. Such system is feasible to be applied in real industry scenarios which are sensitive to environmental changes to precisely control the quality variances.

Data-driven Adaptive Threshold Control for Bike Share Systems / Felisa J. Vazquez-Abad (Hunter College), Michael C. Fu (Robert H. Smith School of Business), and Silvano Bernabel (Hunter College)

When it comes to building a successful public bike share such as the NYC CitiBike system, there are many important questions to answer. There is no shortage of work being done on finding the most efficient way to redistribute bikes to stations. Equally important to how to distribute bikes is the question of when to redistribute bikes. Redistribute too infrequently and customers become frustrated, resulting in decreased revenue. Redistribute too frequently and the cost of redistribution becomes prohibitively high. In this piece of research we attempt to find the optimal time to call for the redistribution of bikes to minimize cost and retain maximum membership.

ARCHITECTURE AND CONSTRUCTION / VERANDA A

Emerging Issues in Construction

Ming Lu (University of Alberta)

A Scenario-based Simulation Framework of on- and off-site Construction Logistics / Ningshuang Zeng, Maximilian Dichtl, and Markus König (Ruhr-University Bochum)

Constructing a building is a very complex process including a vast number and variety of participants, tasks, materials and elements. Interdependencies between the on– and off–site logistics frequently lead to an error–prone and chaotic process. However, good communication can reduce the effects by enabling the different actors to react. Simulation is a classic approach to understand complex problems and has been widely applied in the construction field. Nevertheless, the existing construction simulation approaches still do not consider the entire construction logistics process. This paper proposes a concept to model and simulate on– and off–site construction logistics, to facilitate the understanding of the boundary–spanning dependencies of both on– and off–site domains. A framework is provided, including simulation fundamentals (i.e. logistic BIM model), simulation data preparation (i.e. process pattern definition) and implementation of a scenario–based simulation. Finally, a discussion of the possible benefits and improvements of the proposed approaches is provided.

Criticality Visualization Using 4D Simulation for Major Capital Projects / Michel Guevremont (Hydro-Québec) and Amin Hammad (Concordia University)

In construction, major capital projects are in need of a visualization method

for scheduling and integrating the spatial dimensions with the time dimension. Traditional scheduling methods are limited to the time dimension, and can be used to visualize the critical path of schedules and to compare the criticality of activities. However, they do not consider the spatial constraints. This paper describes a method for developing 4D simulation to visualize the criticality of project activities considering the requirements of the levels of detail. The 4D visualization interface shows the criticality of activities linked to components with color coding based on the total float of each activity. Important benefits can be achieved in supporting decision-making associated with understanding the spatio-temporal constraints related to multiple contracts. Furthermore, the proposed method is useful for filtering, viewing critical and near critical activities, and comparing schedules. The method is tested in a hydroelectric powerhouse case study.

Towards a Conceptual Modeling Framework for Construction Simulation / Mohammed Adel Abdelmegid, Vicente A. González, Michael O'Sullivan, and Cameron G. Walker (The University of Auckland); Mani Poshdar (Auckland University of Technology); and Ashkan M. Naraghi (The University of Auckland)

Discrete event simulation (DES) has been used in academia to solve complex construction management problems for decades. However, it has not gained widespread adoption within the industry. A considerable effort to increase the acceptance of DES in construction has been carried out. However, it has been heavily focused on implementing DES models, neglecting both a detailed conceptualization of the real system and an understanding of stakeholders' requirements. Conceptual modeling (CM) is a fundamental step in DES which helps build stakeholders' trust in the resulting model. We argue, then, that it is vital to develop a CM framework for the construction domain to improve the acceptance of DES in the industry. We propose a domain-specific CM framework for construction application. This framework will be formulated to suit the complex environment of construction projects.

AVIATION MODELING AND ANALYSIS / SIENA

Airport Operations

Miguel Mujica Mota (Amsterdam University of applied Sciences, Amsterdam University of Applied Sciences)

Simulating A Multi-Airport Region To Foster Individual Door-To-Door Travel / Martin Jung (German Aerospace Center)

Airports are intermodal hubs and natural interfaces between ground transport and air transport. In the current DLR project "Optimode.net", an innovative approach is being developed to extend the management of an airport not only to airport landside and terminal processes but to go even further and incorporate feeder traffic in the management of airport processes. Thus providing travelers with a real door-to-door service and letting airport stakeholders benefit from efficient airport management. Technical core of the project is a simulation environment consisting of nine different simulation models with various simulation methods and abstraction levels. In this paper the simulation environment of a multi airport region which is used in the Optimode.net project will be described in detail and also the interaction of the different simulation modules will be explained. We will also show how this complex simulation environment is used to foster individual door-to-door travel and proactive airport management.

Faster Aircraft Boarding Enabled by Infrastructural Changes / Michael Schultz (German Aerospace Center)

Aircraft boarding is a process mainly impacted by the boarding sequence, passenger behaviour and the amount of hand luggage. Whereas these aspects are already addressed in scientific research and operational improvements, the influence of infrastructural changes are only focused upon in the context of future aircraft design. The innovative Side-Slip Seat technology holds the potential for sustainably improving the boarding time by providing a wide aisle during the boarding progress. A comprehensive, validated simulation environment is used to analyse the benefits of this technology and an adapted boarding strategy is identified using evolutionary algorithms. Considering the air transportation environment (e.g. seat load), the passenger behaviour (e.g. conformance), and operational deviations (stochastic model), the Side-Slip Seat could fasten aircraft boarding by at least 20% shorter average boarding time and ensure a more stable boarding progress (smaller standard deviation).

Enhancing the Toolkit of Airport Operations Analysts: Evidence from an Airport Baggage Handling System Improvement Project / Maurizio Tomasella, Paul Hancock, Bilyana Hristova, Zuzana Vancova, and Burak Buke (University of Edinburgh)

We discuss our experience from helping an airport operator and their team of airport operations analysts to introduce discrete-event simulation alongside their existing system improvement/development toolkit. Our project looked at improving the existing baggage handling system of a major European airport run by our partner organization. This paper is divided into two separate but related discussions. First, we collate recent reflections from this project together with those from similar airport projects we have been involved in for the past decade. We discuss a few observations that we believe should help to convince airport operators to develop more in-house skills around both analytical and simulation modeling and analysis, with a focus on the latter. Secondly, we describe one of the simulation components of our baggage handling project and demonstrate the effectiveness of various possibilities to improve the availability and reliability of these systems when operating under tight capacity constraints.

ENVIRONMENT AND SUSTAINABILITY APPLICATIONS / VERANDA D

Environment and health

Josep Casanovas (UPC, Barcelona Supercomputing Center)

Simulation Study in Quantifying Heterogeneous Causal Effects / Jianing Zhao (College of William and Mary), Daniel M. Runfola (AidData), and Peter Kemper (College of William and Mary)

Quantifying the impact of an intervention or treatment in a real setting is a common and challenging problem. For example, we would like to calculate the environmental implications of aid projects in third world countries that target economic development. For causal inference problems of this kind, the Rubin causal model is one of several popular theoretical frameworks that comes with a set of algorithmic methods to quantify treatment effects. However, for a given data set, we neither know the ground truth nor can we easily increase the size of the data set. So, simulation is a natural choice to evaluate the applicability of a set of methods for a particular problem. In this paper, we report findings of a simulation study with four causal inference approaches, namely two single tree approaches (transformed outcome tree, causal tree), and two random forest versions of the former.

A Discrete-Event Simulation Approach to Identify Rules that Govern Arbor Remodeling for Branching Cutaneous Afferents in Hairy Skin / Hyojung Kang, Rachel Orłowsky, and Gregory J. Gerling (University of Virginia)

In mammals, touch is encoded by sensory receptors embedded in the skin. For one class of receptors in the mouse, the architecture of its Merkel cells, unmyelinated neurites, and heminodes follow particular renewal and remodeling trends over hair cycle stages from ages 4 to 10 weeks. As it is currently impossible to observe such trends across a single animal's hair cycle, this work employs discrete event simulation to identify and evaluate policies of Merkel cell and heminode dynamics. Well matching the observed data, the results show that the baseline model replicates dynamic remodeling behaviors between stages of the hair cycle – based on particular addition and removal policies and estimated probabilities tied to constituent parts of Merkel cells, terminal branch neurites and heminodes. The analysis shows further that certain policies hold greater influence than others. This use of computation is a novel approach to understanding neuronal development.

Towards Rapid Population Genetics Forward-in-time Simulations / Victor Sepulveda (CeBiB, Centre for Biotechnology and Bioengineering Santiago, CHILE); Roberto Solar and Alonso Inostrosa-Psijas (CITIAPS, Universidad de Santiago de Chile Santiago, CHILE); Veronica Gil-Costa (CeBiB, CONICET, UNSL San Luis, ARGENTINA); and Mauricio Marin (CeBiB, Centre for Biotechnology and Bioengineering DIINF, Universidad de Santiago de Chile Santiago, CHILE)

Computer simulations are an important tool for the current research in population and evolutionary genetics. They help to understand the genetic evolution of complex processes dynamics that cannot be analytically predicted. The basic idea is to generate synthetic data sets of genetic polymorphisms under user-specified scenarios describing the evolutionary history and genetic architecture

of a species. In this work, we focus on forward-in-time simulations which represent the most powerful, but, at the same time, most compute intensive approach for simulating the genetic material of a population. We present a highly-optimized forward-in-time simulation library called Libgdrift, specially designed to create large sets of replicated simulations. Our simulation library uses code optimizations such as spatial locality and a two-phase data compression approach which allow fast simulation executions, while reducing memory storage. Results show that our proposal can improve the performance reported by well-known simulation software.

HEALTHCARE APPLICATIONS / CHARLESTON C

Addressing Health Care Waiting Times

Mohammad Dehghani (NorthEastern University)

Rationalizing Healthcare Budgeting when Providing Services with Mandated Maximum Delays: A Simulation Modeling Approach / Philip Troy (CIUSSS West-Central Montreal)

To determine the budget needed for the staff needed for mental health services required by new government regulations, a simulation model of the process was built, verified validated, and used to identify where mandated delivery times were not being met, where staff should be reallocated. In addition to the obvious benefits of this approach, a less obvious benefit was that upon the further examination that occurred as part of the discovery process needed to build the model, additional opportunities were found for providing better care with less resources. A final benefit of this work was the potential recognized by the Chief Financial Officer that the approach utilized here could be used throughout the network to rationalize staffing levels, and thus make it possible to provide more, better or timelier outcomes with the same resources throughout the network.

Using Simulation to Help Hospitals Reduce Emergency Department Waiting Times: Examples and Impact / Thomas Monks and Rudabeh Meskarian (University of Southampton)

In recent years, all acute hospitals in the UK have experienced unprecedented emergency department waiting times and hospital bed pressures. The consequences are overcrowded emergency departments, ambulance shortages, cancelled elective operations, low staff morale and financial penalties. To deal with the increasing numbers of patient admissions and delayed discharges hospitals must turn now to modelling and simulation to help increase their flexibility and ability to deal with demand variation. Hospitals face several issues that reduce their flexibility including the need for extreme value-for-money and specialization of care. This talk presents three ED case studies undertaken by an analytics team in the UK. The paper considers the impact of the work and challenges arising from their experiences of simulation modelling in acute hospitals. Final thoughts consider the future of ED simulation.

Improving Patient Waiting Time at a Pure Walk-In Clinic / Haydon D. Reese, Vivekanand Anandhan, Eduardo Perez, and Clara Novoa (Texas State University)

Walk-in clinics have grown in popularity in the United States as a substitute for traditional medical care delivered in primary care clinics and emergency rooms. Walk-in clinics offer an affordable option for basic medical services when compared to a hospital emergency room or an urgent care clinic. This type of medical facility simplifies the health care process for many patients with non-life threatening conditions since no previous appointments are required to see a provider. However, the open access nature and lack of patient scheduling can lead to long wait times for patients or long periods of idle time for providers. In this paper, we derive a discrete event simulation model to study pure walk-in clinics where patients are served without appointments. A case study is discussed that considers a walk-in clinic located in central Texas. The computational study provides useful insights that are applicable to any walk-in health care facility.

LOGISTICS, SCM, TRANSPORTATION / CHARLESTON E

Logistics Case Studies

Loo Hay Lee (National University of Singapore)

Efficient Gate System Operations for a Multi-Purpose Port Using Simulation-Optimization / Ketki Kulkarni (Singapore Management University) and Khiem Trong Tran, Hai Wang, and Hoong Chuin Lau (SMU)

Port capacity is determined by three major infrastructural resources namely, berths, yards and gates. The advertised capacity is constrained by the least of the capacities of the three resources. While a lot of attention has been paid to optimizing berth and yard capacities, not much attention has been given to analyzing the gate capacity. The gates are a key node between the land-side and sea-side operations in an ocean-to-cities value chain. The gate system under consideration, located at an important port in an Asian city, is a multi-class parallel queuing system with non-homogeneous Poisson arrivals. It is hard to obtain a closed form analytical approach for such a system. In this paper, we describe an application of simulation techniques in analyzing the performance of gate operations. Further, we develop an optimization model that is integrated with simulation techniques to suggest efficient lane management policies for an outbound gate system.

A Simulation Tool For Truck Loading At Fuel Filling Plants / Ad Ridder and Ben Cohen (Vrije University Amsterdam) and Bart Mateman (ORTEC Consulting Group)

The various processes of truck loading at a fuel filling plant are interrelated which makes it complex to analyze and improve the performance of the filling plants. This paper describes these processes and presents a software tool developed in FlexSim for modelling the drivers' activities, analyzing different decision scenarios, and optimizing the filling processes at fuel terminals. The simulation model has been used to identify bottlenecks and evaluating opportunities for performance improvement. This paper reports the application of the model to a lubricant filling plant for analyzing and supporting decision making on the assignment of trucks to bays, and on the availability of the lubricants on the fuel arms at the lading bays.

Empty Container Stacking Operations: Case Study of an Empty Container Depot in Valparaíso Chile / Felipe Hildago, Diego Aranda, and Jimena Pascual (PUCV); Alice E. Smith (Auburn University); and Rosa Gonzalez (University of Los Andes)

This paper describes a detailed stochastic simulation model integrated with a transactional database to model operations in an empty container depot. Empty container depots are found ubiquitously in supply chains around the world but there has been virtually no quantitative research done to assess operational policies nor layout designs. In this work we determine the performance of operational policies related to the stacking and retrieval of empty containers to derive recommendations for policy improvements and, in future work, the yard layout design. A simulation model was chosen as the proper tool to address these aims because of the uncertain nature and complex handling actions of an empty container depot. Results thus far show that policies concerning remarshaling and retrieval strongly influence the efficiency of the depot operations in terms of the truck turnaround times of trucks, as well as the utilization of the resources which include yard cranes and personnel.

MASM / VERANDA E

Planning Methods

Reha Uzsoy (North Carolina State University)

On Agent-Based Modeling In Semiconductor Supply Chain Planning / Sebastian Achter (Hamburg University of Technology); David Meyer-Riehl (Infineon Technologies AG); Iris Lorscheid and Jonas Hauke (Hamburg University of Technology); Can Sun, Thomas Ponsignon, and Hans Ehm (Infineon Technologies AG); and Matthias Meyer (Hamburg University of Technology)

Supply chain (SC) planning in the semiconductor industry is challenged by high uncertainties on the demand side as well as a complex manufacturing process with non-deterministic failure modes on the production side. Understanding the complex interdependencies and processes of a SC is essential to realize opportunities and mitigate risks. However, this understanding is not easy to

achieve due to the complexity of the processes and the non-deterministic human behavior determining SC planning performance. Our paper argues for an agent-based approach to understand and improve SC planning processes using an industry example. We give an overview of current work and elaborate on the need for integrating human behavior into the models. Overall, we conclude that agent-based simulation is a valuable method to identify favorable and unfavorable conditions for successful planning.

Incorporating Elements of a Sustainable and Distributed Generation System Into a Production Planning Model for a Wafer Fab / Timm Ziarnetzky (University of Hagen), Thulasi Kannaian and Jesus Jimenez (Texas State University), and Lars Moench (University of Hagen)

We consider elements of a sustainable and distributed generation system for a wafer fab. Wind turbines (WTs), solar photovoltaics (PVs), a substation with grid access, and a net metering system are included in the generation system. WTs and solar PVs have the highest priority in supplying electricity. Surplus energy can be returned to the main grid. The objective function of the production planning formulation contains production-related costs, cost for energy from the substation, and penalty costs when a renewable energy penetration is not reached. This cost can be reduced by offering surplus energy to the main grid. The production plans are executed in a simulation environment to compute the profit in the face of machine breakdowns, wind power volatility, and uncertain power output of the PVs. The approach allows determining an appropriate number of WTs and solar PVs for demand scenarios. We present results of simulation experiments with the model.

Robust Approaches for Estimating Clearing Functions / Erinc Albey and Ihsan Yanikoglu (Ozyegin University) and Reha Uzsoy (North Carolina State University)

Although production planning models using nonlinear CFs have shown promising results for semiconductor wafer fabrication facilities, the lack of an effective methodology for estimating the CFs is a significant obstacle to their implementation. Current practice focuses on developing point estimates using least-squares regression approaches. This paper compares the performance of a production planning model using a multi-dimensional CF and its robust counterpart under several experimental settings. As expected, as the level of uncertainty is increased, the resulting production plan deviates from the optimal solution of the deterministic model. On the other hand, production plans found using the robust counterpart are less vulnerable to parameter estimation errors.

MANUFACTURING APPLICATIONS / CHARLESTON B

Manufacturing Applications I

Sanjay Jain (The George Washington University)

Module-Based Modeling and Analysis of Just-In-Time Production Adopting Dual-Card Kanban System and Mizusumashi worker / Kanna Miwa (Nagoya Gakuin University), Junichi Nomura (Seijoh University), and Soemon Takakuwa (Chuo University)

In this study, we design and develop module-based modeling scheme that can conveniently represent a manufacturing system adopting a dual-card kanban system with a delivery cycle. By combining the designed modules, it is possible to express models of various systems comprising multiple parts, production lines, suppliers, and Mizusumashi (fixed-course pick-up). The module-based modeling scheme is useful for understanding the characteristics of just-in-time manufacturing and helping decision makers build simulation models based on the modules. We focus on modularization of the assembly line and the parts carrying Mizusumashi in a JIT manufacturing system. The proposed modules have focused dialogs, animation, and modeling functionality. In addition, a procedure for finding the optimal number of tray containers and kanbans to achieve no stock-out events is proposed based on the simulation model that integrates the kanban system and the Mizusumashi system. Then, the proposed procedure is applied to a numerical example.

Using Simulation to Determine the Safety Stock Level for Intermittent Demand / Fredrik Persson (Linköping University); Minna Axelsson (Siemens Industrial Turbomachinery); and Fredrik Edlund, Christoffer Lanshed, Agnes Lindström, and Frida Persson (Linköping University)

Safety stock calculations are difficult for products with intermittent demand,

long production lead times, and high monetary values. Theoretically, forecasts can be used to reduce the need for safety stocks. A high precision forecast minimizes the need for safety stock and forecast evaluation measurements can be used to calculate the safety stock level. However, a more realistic determination of safety stock levels can be obtained by simulation. In this paper, simulation is used to model and experiment on a case with three end products in order to determine the relationship between safety stock levels and service levels. Also, a comparison is made with theoretically calculated safety stocks to see how well basic theoretical models for safety stock calculations fulfill the requirements of service level. The result is that simulation can provide a much more accurate determination of safety stock levels for intermittent demands than theoretical calculations.

Simulation of Maintenance Activities for Micro-Manufacturing Systems by Use of Predictive Quality Control Charts / Daniel Rippel and Michael Lütjen (BIBA - Bremer Institut für Produktion und Logistik GmbH at the University of Bremen) and Michael Freitag (University of Bremen)

In micro manufacturing, the determination and scheduling of maintenance activities can strongly impact the production efficiency of the corresponding production system. Thereby, the supervision of quality relevant parts, tools and components can be very complex, due to the limited spaces within the manufacturing devices. This article proposes an extension of quality control charts by adding predictive component. This component predicts at which point in time maintenance activities are required based on quality characteristics of the produced work pieces. The article further presents two simulation studies. These demonstrate that the extended approach can compete with will configured time-based maintenance strategies in terms of production efficiency and rejection rates. In addition the predictive nature of this extension can issue forewarning for tool wear induced quality defects very early during production, allowing for an suitable integration of maintenance activities into the production schedule.

MILITARY, HOMELAND SECURITY AND EMERGENCY RESPONSE / CHARLESTON A

Military Keynote

Raymond Hill (Air Force Institute of Technology)

Military Simulation: A Ubiquitous Future / Douglas D. Hodson (Air Force Institute of Technology)

Douglas D. Hodson is an Associate Professor of Software Engineering with the Air Force Institute of Technology. He received a B.S. in Physics from Wright State University in 1985, and both an M.S. in Electro-Optics in 1987 and an M.B.A. in 1999 from the University of Dayton. He completed his Ph.D. at the Air Force Institute of Technology in 2009. He has over 25 years of experience in the domain of modeling and simulation, including mixed reality and distributed virtual simulations. He is active in the 9-University Science of Test Research Consortium supported by the Office of Secretary of Defense leading the work in the Live, Virtual and Constructive simulation initiative and is the lead technical developer and project manager for the open-source Mixed Reality Simulation (MIXR) Platform which has been used to develop a wide variety of standalone and distributed simulation applications. His email address is douglas.hodson@afit.edu.

SIMULATION EDUCATION / VISTAS

Human Simulation: At the Intersection of Simulation Engineering and the Humanities

Saikou Diallo (Virginia Modeling, Analysis and Simulation Center)

Teaching at the Intersection of Simulation and the Humanities / Wesley Wildman (Center for Mind and Culture), Paul Fishwick (The University of Texas at Dallas), and LeRon Shults (University of Agder)

Human simulation (applying Modeling and Simulation (M&S) to topics in the humanities, the interpretative social sciences, and the arts) is a potent extension of social simulation. This paper offers reflections on teaching at this intersection, presenting best practices in pedagogy for undergraduate and graduate students engaged in formal studies, and for established researchers having no structured curriculum. The fact that human simulation is possible drives home the presence of formal patterns in a host of phenomena that for a long time were thought to be inimical to mathematical analysis. That implies a double pedagogical

challenge: teaching humanities students to recognize formal structures in the phenomena they study (counter-intuitive for them), and teaching M&S students to collaborate with humanities people who think very differently (equally counter-intuitive). The three perspectives presented here underline the usefulness of human simulation, as well as the difficulties and benefits associated with teaching and learning human simulation.

SOCIAL AND BEHAVIORAL SIMULATION / VISTAS

Human Simulation: At the Intersection of Simulation Engineering and the Humanities

Saikou Diallo (Virginia Modeling, Analysis and Simulation Center)

Teaching at the Intersection of Simulation and the Humanities / Wesley Wildman (Center for Mind and Culture), Paul Fishwick (The University of Texas at Dallas), and LeRon Shults (University of Agder)

Human simulation (applying Modeling and Simulation (M&S) to topics in the humanities, the interpretative social sciences, and the arts) is a potent extension of social simulation. This paper offers reflections on teaching at this intersection, presenting best practices in pedagogy for undergraduate and graduate students engaged in formal studies, and for established researchers having no structured curriculum. The fact that human simulation is possible drives home the presence of formal patterns in a host of phenomena that for a long time were thought to be inimical to mathematical analysis. That implies a double pedagogical challenge: teaching humanities students to recognize formal structures in the phenomena they study (counter-intuitive for them), and teaching M&S students to collaborate with humanities people who think very differently (equally counter-intuitive). The three perspectives presented here underline the usefulness of human simulation, as well as the difficulties and benefits associated with teaching and learning human simulation.

Monday 12:20p.m.-1:20p.m.

TITAN KEYNOTE / SUMMERLIN BALLROOM

Titan Talk - Bernard P. Zeigler

Gabriel Wainer (Carleton University)

Why Should We Develop Simulation Models in Pairs? / Bernard P. Zeigler (University of Arizona)

The conventional approach to model construction for simulation is to focus on a single model and follow a more or less structured development cycle. Why we put in twice the time and effort to develop two models rather than one? The answer lies in the fact that like most greedy heuristics, short-sightedness at the beginning may be much more costly in the end. This talk will champion the cause of the pairs-of-models (perhaps families of models) with discussion of multiresolution modeling. We show how the pair-of-models approach leads to better results overall than construction of a complex model followed by a simpler model developed subsequently by necessity under stress when complexity overwhelms. Benefits include the ability to perform mutual cross-calibration, avoiding the usual difficulties in harmonization of the underlying ontologies as well as ability to better reconcile and correlate predictions of referent system outcomes.

BERNARD P. ZEIGLER is Chief Scientist at RTSync Corp., Professor Emeritus of Electrical and Computer Engineering at the University of Arizona (UA) and Affiliated Research Professor in the C4I Center at George Mason University. He is internationally known for his seminal contributions in modeling and simulation theory. He has published several highly cited books including "Theory of Modeling and Simulation" (3rd edition in process) and "Guide to Modeling and Simulation of Systems of Systems." He is the originator of the Discrete Event System Specification (DEVS) formalism in 1976 which has spurred the development of a world-wide research community, with its own conference meetings, and research/technology awards. In 1995, Zeigler was named Fellow of the IEEE in recognition of his contributions to the theory of discrete event simulation. Dr. Zeigler co-founded the Arizona Center for Integrative Modeling and Simulation (ACIMS) in 2001 dedicated to the development of modeling and simulation as a discipline of the future. Dr. Zeigler has been the lead architect of multiple web-based systems in complex systems that incorporate unique behaviors derived from DEVS-based properties. He is also Fellow of the Society

for Modeling and Simulation International and member of its Hall of Fame. He received the Lifetime Achievement Award from INFORMS in 2016. His email address is zeigler@ece.arizona.edu.

Monday 1:30p.m.-3:00p.m.

HISTORY OF SIMULATION / TRAILS

International Simulation History with Keynote

Robert G. Sargent (Syracuse University)

A History of Simulation Development in the UK / Brian W. Hollocks (Bournemouth University)

Discrete-event simulation first emerged in the late 1950s and steadily grew in popularity to become the most frequently used of the classical Operational Research techniques across a range of industries and users. The leading advances in the evolution of discrete-event simulation software came from the United Kingdom and the USA and this presenter was engaged for some 30 years with its development and use. The presentation reviews that history as a first-hand account, specifically in the United Kingdom.

BRIAN HOLLOCKS is in the process of retiring as Professor of Management Science at Bournemouth University whom he joined in 1994 as the INTEL Chair in Computer Supported Co-operation. His lecturing and research included simulation, computer supported cooperative work, knowledge management, and artificial intelligence. Prior to being an academic, he was in business and industry, primarily in operational research and software development/marketing. This included some 30 years in the development and use discrete-event simulation software systems. He is a Mechanical Engineering graduate and holds a PhD in Management Science from Southampton University. His email address is brian.hollocks@gmail.com.

The Countries of the Participants in the Winter Simulation Conference / Dave Goldsman and Mariana de Almeida Costa (Georgia Institute of Technology) and Paul Goldsman (self-employed)

For 50 years, the Winter Simulation Conference (WSC) has brought together researchers and practitioners from the field of discrete-event simulation. This paper discusses the demographics of the authors of the many thousands of papers that have appeared in the WSC proceedings over that time span. From its origins as a “regional” conference whose participants hailed primarily from the United States, we shall see that the WSC has evolved into a truly top-flight, international conference.

INTRODUCTORY TUTORIALS / RED ROCK G

Introduction to Information and Process Modeling for Simulation

Alberto Falcone (University of Calabria)

Introduction to Information and Process Modeling for Simulation / Gerd Wagner (Brandenburg University of Technology)

In simulation engineering, a system model mainly consists of an information model and a process model. In the fields of Information Systems and Software Engineering (IS/SE) there are widely used standards such as the Class Diagrams of the Unified Modeling Language (UML) for making information models, and the Business Process Modeling Notation (BPMN) for making process models. This tutorial presents a general approach how to use UML class diagrams and BPMN process diagrams at all three levels of model-driven simulation engineering: for making conceptual simulation models, for making platform-independent simulation design models, and for making platform-specific, executable simulation models. In our approach, object and event types are modeled as stereotyped classes and random variables are modeled as stereotyped operations constrained to comply with a specific probability distribution, while event rules/routines are modeled both as BPMN patterns and in pseudo-code.

ADVANCED TUTORIALS / VERANDA C

Restraining Complexity and Scale Traits for Component-based Simulation Models

Philip A. Wilsey (University of Cincinnati)

Restraining Complexity and Scale Traits for Component-based Simulation Models / Hessam S. Sarjoughian (Arizona State University)

From understanding our distant past to building systems of future, useful simulations demand “efficient models”. Standing in the way is the twofold challenge of restraining complexity and scale of models. We describe these traits in view of component-based model development. We substantiate the roles complexity and scale play in view of modeling formalisms. We propose semi-formal modeling methods, in contrast to formal, are suitable for qualifying/quantifying model complexity and scale. For structural abstractions, we use class and component models. For behavioral abstractions, we use activity and state machines models. Furthermore, we consider these traits from the vantage point of having families of component-based models. We exemplify the concept and approach by developing families of DEVS models in the CoSMoS framework supporting DEVS-based activity and state machines models that persist in relational databases across multiple model development sessions. We conclude by discussing future research directions for real-time and heterogeneous model composability.

MODELING METHODOLOGY / RED ROCK I

Parallel Simulation

Jason Liu (Florida International University)

Virtual Time III: Unification of Conservative and Optimistic Synchronization in Parallel Discrete Event Simulation / David Jefferson and Peter Barnes (Lawrence Livermore National Laboratory)

There has long been a divide in synchronization approaches for parallel discrete event simulation, between conservative methods requiring lookahead and optimistic methods requiring rollback. These are usually seen as dichotomous, so that a model writer must make an early, static design decision between them. An optimistic simulator does not need lookahead information but is unable to take advantage of it even if it were available, whereas a conservative simulator may perform poorly or even deadlock without good lookahead information. Here we introduce unified virtual time (UVT) synchronization which provides the advantages of both conservative and optimistic synchronization dynamically for all models. Conservative synchronization becomes an accelerator for optimistic synchronization. When lookahead information is available the simulation will execute conservatively. Otherwise it will execute optimistically. In this paper we present UVT, argue for its correctness, and show adaptations of Time Warp, YAWNS, and Null Messages which cooperatively synchronize a single simulation.

A Work-stealing based Dynamic Load Balancing Algorithm for Conservative Parallel Discrete Event Simulation / Wenjie Tang and Yiping Yao (National University of Defense Technology), Xiao Song (Beihang University), and Feng Zhu and Tianlin Li (National University of Defense Technology)

In the past few years, we have witnessed an increased interest in using multithreading PDES on multicore platforms. The work-stealing scheme, which towards to general multithread computing, can be utilized in PDES to achieve load balance straightly. However, to the best of our knowledge, the work-stealing scheme has only served as a competitor, instead of a cooperator, to other load balancing algorithm. In this paper, we propose a work-stealing based dynamic load balancing algorithm (WS-DLB) with the aim of combining their advantages. It adaptively rebalances the LPs distribution based on a priori estimation, and uses a greedy lock-free work-stealing scheme to eliminate bias at runtime. In addition, these two schemes are well adapted to enhance each other. We analyze the performance characteristics of the proposed algorithm by means of a synthetic benchmark. Experiments demonstrate that our WS-DLB algorithm achieves better performance.

Energy Consumption of HLA Data Distribution Management Approaches / SaBra A. Neal and Richard M. Fujimoto (Georgia Institute of Technology)

Energy and power aware data distribution methods are essential for using these approaches in energy constrained devices and environments. Data Distribution

Management (DDM) is a set of services defined in the High Level Architecture (HLA) that aims to efficiently propagate distributed simulation state information. This paper describes an empirical study of the energy consumption of computation and communication components of region based and grid based DDM approaches in mobile devices. Experimental data illustrate that region based approaches tend to consume more energy than grid based approaches for computations, but less for communications. These results also show that the choice of grid cell size and grid cell constraints on publication regions can play an important role in the energy efficiency of grid based approaches.

AGENT-BASED SIMULATION / RED ROCK H

Urban Planning and Resource Conservation

Ashkan Negahban (Penn State University)

Agent-based Modeling Framework for Simulation of Complex Adaptive Mechanisms Underlying Household Water Conservation Technology Adoption /

Kambiz Rasoulkhani (Texas A&M University); Brianne Logasa (University of California Los Angeles, University of California San Diego); Maria Presa Reyes (Florida International University); and Ali Mostafavi (Texas A&M University)

The objective of this study was to specify and model the behavior of households regarding the installation of water conservation technology and evaluate strategies that could potentially increase water conservation technology adoption at the household level. In particular, this study created an agent-based modeling framework in order to understand various factors and dynamic behaviors affecting the adoption of water conservation technology by households. The model captures various demographic characteristics, household attributes, social network influence, and pricing policies; and then evaluates their influence simultaneously on household decisions in the adoption of water conservation technology. The application of the proposed simulation model was demonstrated in a case study of the City of Miami Beach. The simulation results identified the intersectional effects of various factors in household water conservation technology adoption and also investigated the scenario landscape of the adoptions to inform policy formulation and planning.

Modeling and Simulating Households and Firms Location Choice Using Agent-based Models: Application to the Urban Area of Bordeaux /

Youssef Bouanan, Seghir Zerguini, and Nathalie Gaussier (University of Bordeaux)

This article aims to respond to growing concerns about sustainable urbanization, which in recent years have generated a need for prospective assessment in the field of transport and land-use planning, by predicting future land-use development. We introduce a Land Use model (part LU of a Land Use Transport Interaction model) which aims to simulate households and firms location choice within an urban system.. We use the agent-based approach to simulate location choices in order to account for land use changes and to estimate residential and economic activities location. This is a dynamic bottom-up approach with the households and the firms as their basic components. The MUST-B model considers the agents' location choices according to the utility theory and the equilibrium between real estate supply and demand. The model is used to simulate urban land-use development in the urban area of Bordeaux, France.

An Agent Based Model For Joint Placement of PV Panels and Green Roofs /

Xueping Li, Mohammad Ramshani, and Anahita Khojandi (University of Tennessee, Knoxville); Olufemi Omitaomu (Oak Ridge National Laboratory); and Jon Michael Hathaway (University of Tennessee, Knoxville)

Photovoltaic panels generate electricity directly from sunlight, making them a favored renewable technology. Green roofs are rooftops covered with vegetation, which provide a variety of benefits, namely, reducing stormwater runoff, improving air quality, and biodiversity. Green roofs are capable of improving the efficiency of Photovoltaic panels, as shown by the recent studies. Optimal placement of Photovoltaic panels and green roofs is a challenging problem due to the complications imposed by uncertainties associated with future climate conditions, specifically due to climate change. An agent based model to optimally place Photovoltaic panels and green roofs is developed in this study. We propose a tabu search metaheuristic algorithm to solve the developed model. Then, a real-world case for a mid-sized city in the U.S. is solved as a case study for the model. We further conduct numerical analysis and provide insights.

HYBRID SIMULATION / HILLS**Simulation & Analytics - 2**

Tillal Eldabi (Brunel University)

A Global and Local Search Approach to Quay Crane Scheduling Problem / Kyrlo Perelygin (NVIDIA) and Joseph J. Kim (California State University Long Beach)

The container flow in terminals at a port is often bottlenecked due to the slow operations of the quay cranes in a scarce terminal land space. The quay crane scheduling problem (QCSP) is a major problem because of the assignment of expensive quay cranes to multiple vessel-holds for container discharging and loading operation. This paper presents a hybrid QCSP Solver, which combines genetic algorithms for global search with steepest ascent hill climbing for local search. Numerical experiments are performed with small- and large-sized random QCSP instances. The experimental results revealed that the hybrid QCSP Solver provides a better solution than the stand-alone QCSP Solver. By scheduling the dynamic operation of quay cranes it is expected that the developed decision making tool will provide terminal planners with a guideline to enhancing the assignment of quay cranes to a vessel.

A Bayesian Simulation Approach for Supply Chain Synchronization / Bianica Pires, Joshua Goldstein, and Dave Higdon (Virginia Tech); Shane Reese (Brigham Young University); Paul Sabin and Gizem Korkmaz (Virginia Tech); Shan Ba, Ken Hamall, and Art Koehler (Procter & Gamble); and Stephanie Shipp and Sallie Keller (Virginia Tech)

While simulation has been used extensively to model supply chain processes, the use of a Bayesian approach has been limited. However, Bayesian modeling brings key advantages, especially in cases of uncertainty. In this paper, we develop a data informatics model that could be used to realize a digital synchronized supply chain. To realize this model, we take a hybrid approach that combines Bayesian modeling with discrete-event simulation and apply it to the supply chain process of a Procter & Gamble (P&G) manufacturing and distribution facility. We use approximately one year of transactional data to inform our model, including information on customer orders, production, raw materials, inventory, and shipments. A driving force for creating this model is to better understand and manage the balance between inventory, profit, and service.

A Hybrid Approach Using Forecasting and Discrete-Event Simulation for Endoscopy Services / Alison Harper and Navonil Mustafee (University of Exeter) and Mark Feeney (Torbay and South Devon NHS Foundation Trust)

Healthcare services worldwide are prioritizing efficiency of delivery and optimization of resource allocation. Efficient healthcare delivery relies on the coordination of demand and capacity, but forecasting studies often predict demand without regard for future capacity constraints. Likewise, capacity planning requires strategic decision-making, therefore planning tools should allow decision-makers to examine the consequences of changing demand and likely capacities required over time. The aim of the study is to evaluate a hybrid methodology using discrete-event simulation and demand forecasting in the healthcare domain. A case-study investigates the application of official population projections with local historical demand data to forecast demand for a healthcare diagnostic service. The resultant forecasts are then used with DES in a hybrid systems modeling approach. This provides plausible demand forecasts for future capacity planning and resource allocation in a preventative healthcare service. It also contributes to debates on the value of hybrid approaches in supporting real-world decision-making.

ANALYSIS METHODOLOGY / VERANDA B**Interpolation and Parameters**

Jason Veneman (MITRE)

Fitting Continuous Piecewise Linear Poisson Intensities via Maximum Likelihood and Least Squares / Zeyu Zheng and Peter W. Glynn (Stanford University)

We investigate maximum likelihood (ML) and ordinary least squares (OLS) methods to fit a continuous piecewise linear (PL) intensity function for non-homogeneous Poisson processes. The estimation procedures are formulated as convex optimization problems that are highly tractable. We also study the model mis-specification issues for ML and OLS in settings where the point

process is non-Poisson or the underlying intensity is not piecewise linear. Through the computational study, the performances of ML and OLS estimators are exhibited. The customer arrival process to a large U.S. bank call center is studied using our methods.

Stochastic Co-Kriging for Steady-State Simulation Metamodeling / Xi Chen (Virginia Tech) and Sahar Hemmati and Feng Yang (West Virginia University)

In this paper we present the stochastic co-kriging methodology (SCK) for approximating a steady-state mean response surface based on outputs from both long and short simulation replications performed at selected design points. We provide details on how to construct an SCK metamodel, perform parameter estimation, and make prediction via SCK. We demonstrate numerically that SCK holds the promise of providing more accurate prediction results at no additional computational effort by only externally adjusting the simulation runlength and number of independent replications of simulations through the experimental design of the simulation study.

Asymmetric Kriging Emulator for Stochastic Simulation / QIONG Zhang (Virginia Commonwealth University) and Wei Xie (Rensselaer Polytechnic Institute)

In many situations, e.g., simulation optimization and input uncertainty quantification, we need to assess the system performance at a large number of alternative inputs. Since each simulation run could be computationally expensive, statistical emulator could efficiently use the simulation budget to estimate the system performance. This paper proposes a new emulator for stochastic simulation, called asymmetric kriging (AK), which can be used to emulate the distribution of stochastic simulation outputs at each input point. Different from existing methods in the simulation literature, our approach does not require strong assumptions on either the functional form of the response surface or the normal distribution of the simulation estimation error. Numerical studies indicate the efficacy of our approach compared to alternative methods in the literature.

SIMULATION OPTIMIZATION / PAVILION

Random/Heuristic Search

Zelda Zabinsky (University of Washington)

A Computational Comparison of Simulation Optimization Methods using Single Observations within a Shrinking Ball on Noisy Black-Box Functions with Mixed Integer and Continuous Domains / David D. Linz and Zelda B. Zabinsky (University of Washington), Seksan Kiatsupaibul (Chulalongkorn University), and Robert Smith (University of Michigan)

We focus on simulation optimization algorithms that are designed to accommodate noisy black-box functions on mixed integer/continuous domains. There are several approaches used to account for noise which include aggregating multiple function replications from sample points and a newer method of aggregating single replications within a “shrinking ball.” We examine a range of algorithms, including, simulated annealing, interacting particle, covariance-matrix adaption evolutionary strategy, and particle swarm optimization to compare the effectiveness in generating optimal solutions using averaged function replications versus a shrinking ball approximation. We explore problems in mixed integer/continuous domains. Six test functions are examined with 10 and 20 dimensions, with integer restrictions enforced on 0%, 50%, and 100% of the dimensions, and with noise ranging from 10% to 20% of function output. This study demonstrates the relative effectiveness of using the shrinking ball approach, demonstrating that its use typically enhances solver performance for the tested optimization methods.

Multi-Fidelity Simulation Optimization with Level Set Approximation Using Probabilistic Branch and Bound / David D. Linz (University of Washington), Hao Huang (Yuan Zu University), and Zelda B. Zabinsky (University of Washington)

Simulated systems are often described with a variety of models of different complexity. Making use of these models, algorithms can use low complexity, “low-fidelity” models or meta-models to guide sampling for purposes of optimization, improving the probability of generating good solutions with a small number of observations. We propose an optimization algorithm that guides the search for solutions on a high-fidelity model through the approximation of a level set from a low-fidelity model. Using the Probabilistic Branch and Bound algorithm to approximate a level set for the low-fidelity model, we are able to efficiently locate solutions inside of a target quantile and therefore reduce the

number of high-fidelity evaluations needed in searches. The paper provides an algorithm and analysis showing the increased probability of sampling high-quality solutions within a low-fidelity level set. We include numerical examples that demonstrate the effectiveness of the multi-fidelity level set approximation method to locate solutions.

A Two-Time-Scale Adaptive Search Algorithm for Global Optimization / Jiaqiao Hu and Qi Zhang (State University of New York at Stony Brook)

We study a random search algorithm for solving deterministic optimization problems in a black-box scenario. The algorithm has a model-based nature and finds improved solutions by sampling from a distribution model over the feasible region that gradually concentrates its probability mass around high quality solutions. In contrast to many existing algorithms in the class, which are population-based, our approach combines random search with a two-time-scale stochastic approximation idea to address a certain ratio bias inherent in these algorithms and uses only a single candidate solution per iteration. We prove global convergence of the algorithm and carry out numerical experiments to illustrate its performance.

ARCHITECTURE AND CONSTRUCTION / VERANDA A

Simulation for Sustainable Construction

Markus König (Ruhr-University Bochum)

Carbon Dioxide Emission Evaluation in Construction Operations Using DES: A Case Study of Carwash Construction / Zhidong Li and Reza Akhavian (California State University East Bay)

This study aims to assess the carbon dioxide emission of carwash construction operation by applying computer-based simulation modeling. Discrete event simulation (DES) serves as an effective way to functionally evaluate carbon dioxide emission of a typical carwash construction. The DES model makes it possible to efficiently simulate and analyze carbon dioxide emission factors. This in turn requires project participants to find ways to decrease inverse environmental effects of the projects to respond to the increasing concern on such issues. This study is carried out by studying the process, data analysis, and simulation of the construction operation using Visio, Excel, and EZStrobe computer software. This simulation tool is practical for project participants and will offer them an idea of carbon dioxide emission in more realistic scenarios during construction operation.

Simulating Total Embodied Energy of Building Products through BIM / Raja Shahmir Nizam, Yue Xiao, Tongpo Zhang, Yuelong Liu, and Cheng Zhang (Xian Jiaotong Liverpool University)

The total energy involved in building construction and operation can be divided in two parts, Operational Energy and Embodied energy. Many researches have focused on simulating operation energy but the embodied energy is not much discussed for simulation or alternative selection purposes. A lot of complex variables need to be quantified and analyzed for optimization of embodied energy. Building Information Model (BIM) is used as a platform to hold the data as a context aware, intelligent and interactive database. This paper discusses the means for realizing the embodied energy data in the BIM model through linking the model with external databases thus laying a foundation for the data exchange and retention needed to perform the simulations in the next phase of research. Plug-ins are developed to calculate the embodied energy for different scenarios. Finally, a case study is conducted of a simplified manufacturing plant to implement the proposed methodology.

Simulating a Ready-mix Concrete Plants Network Using Multimethod Approach / Jaime Alberto Sánchez Velásquez (Universidad EIA) and Maria Camila Aristizábal Isaza (Cementos Argos S.A.)

The operation of ready-mix concrete (RMC) plants is strongly affected by the complex stochastic nature of the concrete production and delivery processes. The delivery compliance in the different building sites is one of the most significant aspects for both customer satisfaction and resource allocation in the RMC industry. To improve the decision-making process in the RMC industry, a multi-method (using a hybrid Agent-based and Discrete-Event simulation modeling technique) simulation model was created for a multinational company that produces and markets cement and ready-mixed concrete using software Arena, Rockwell Automation. The main contribution of this work is the novel

approach to designing travel time to the construction sites, improving its validity and allowing us to optimize the production and delivery program. Results obtained in this project were used in the decision making process regarding the effective use of capital in installed capacity while minimizing risk.

AVIATION MODELING AND ANALYSIS / SIENA

Aircraft Trajectory Modeling for Safety and Efficiency

Miguel Mujica Mota (Amsterdam University of applied Sciences, Amsterdam University of Applied Sciences)

Rare Event Simulation for Potential Wake Encounters / Azin Zare-Noghabi and John Shortle (George Mason University)

A flying aircraft produces two coherent rotating vortices of air in its trail. If another aircraft flies into one of these vortices, it can experience an uncommanded roll. Because of the potential risk, wake separation standards exist to significantly reduce the probability of such events. Thus, wake encounters are inherently rare. As new procedures and technologies are proposed to increase the capacity of the airspace, rare-event simulation is necessary to evaluate the safety of proposed changes. This paper explores the performance of a rare-event splitting technique in the context of estimating probabilities of potential wake encounters. The goal is to identify good strategies for the splitting method while using a relatively simple model for the wakes. Suggestions for the choice of the level function and the locations of levels are given.

A Study on Modeling Techniques for Fuel Burn Estimation based on Flight Simulator Experiment Data / Navinda Kithmal Wickramasinghe, Daichi Toratani, Sachiko Fukushima, and Hiroko Hirabayashi (Electronic Navigation Research Institute)

The ever-increasing demand for global air travel provokes many daunting challenges for the aviation industry in meeting future requirements. Estimation of fuel consumption plays a central role in aircraft performance evaluation, which is vital in understanding and validating key components of a future air traffic management system. This study provides a framework for a quantitative evaluation on fuel burn estimation with the objective of proposing modeling techniques to accurately assess the aircraft performance. Data from a series of continuous descent operations simulations conducted on full-flight simulator are used as reference data. Base of Aircraft Data (BADA) aircraft performance model data provided by Eurocontrol are integrated with point mass dynamics to estimate fuel flow in both clean and non-clean configurations of the aircraft. Statistical results show the model can estimate the total fuel consumption within $\pm 6\%$ of actual value with $\pm 6\%$ and $\pm 10\%$ for cruise and descent phases respectively.

Design Methodology to Simulate Continuous Descent Operations at Kansai International Airport / Daichi Toratani, Navinda K. Wickramasinghe, Sachiko Fukushima, and Hiroko Hirabayashi (Electronic Navigation Research Institute)

One of the hot topics in the field of air traffic management is continuous descent operations, which is one of the efficient descent procedure to an airport. In Japan, the continuous descent operations are implemented at Kansai International Airport, but its applicability is limited to only the non-congestion period owing to the unpredictability of the trajectory and arrival time of the continuous descent operations as compared to the conventional operations. To expand the time period for the continuous descent operations, in this paper, we develop a fast-time simulator. The simulator can provide the predicted trajectory and arrival time of the continuous descent operations. The prediction accuracy is reviewed by comparison with the results of the simulation conducted on a full flight simulator. Discussions on accuracy improvement of the prediction have been provided considering available data for air traffic controllers through radar data systems.

ENVIRONMENT AND SUSTAINABILITY APPLICATIONS / VERANDA D

Environment and energy

Alessandro Pellegrini (Sapienza, University of Rome)

Energy Simulation In Dynamic Production Networks (ESProNet): Simulation For Industrial Symbiosis / Martin Maiwald, Linda Kosmol, Christoph Pieper, and Thorsten Schmidt (Technische Universität Dresden) and Alex Magdanz (ESI ITI GmbH)

Industrial symbiosis provides several positive aspects regarding energy and material efficiency, but it is also a challenging concept due to additional dependencies in a production cluster. As a consequence the risks inherent to these partnerships are high and thus the concept is not widely used. The project ESProNet supports the analysis and assessment of industrial symbiosis in a given cluster via simulation and research of altered scenarios. This paper contains the first steps in the project including the ontology to breakdown the complex problem as well as the modeling approach for the components in a new library based on material and energy balances. A proof of concept with the simulation of an industrial symbiosis cluster containing a server providing waste heat to an office building shows a great potential with up to 20 % less energy input for heat.

Integrating Consumer Preferences in Renewable Energy Expansion Planning Using Agent-based Modeling / Anuj Mittal and Caroline C. Krejci (Iowa State University)

As share of renewable sources in the energy sector is increasing, the energy production and distribution network's centralized structure is changing to numerous small-scale distributed networks. Energy consumers in the residential sector are increasingly becoming energy producers by adopting rooftop photo voltaic (PV) systems. However, increasing rooftop PV adoption has contributed to diminishing revenues for utility companies. This paper describes an agent-based model that has been developed to help utility companies better understand the impacts of consumers' preferences and behaviors on adding renewable sources to their energy mix. Experimental results demonstrate that including both consumers and utility companies as stakeholders can help the utilities alleviate revenue losses due to increasing rooftop PV adoption while meeting their renewable energy expansion targets.

Artificial Neural Network Models for Building Energy Prediction / Ki Uhn Ahn and Cheol Soo Park (Sungkyunkwan University)

There is a national need for a quick and easy building energy performance assessment system of existing buildings, without resorting to dynamic building energy simulation tools which usually require significant cost, time and expertise. In this study, the authors report the development of a building energy profiling system which is based on Artificial Neural Network (ANN) models. The ANN models were made by a series of EnergyPlus pre-simulations sampled by a Monte Carlo technique. The MBE and CVRMSE between EnergyPlus and ANN models are 1.53% and 7.82%, respectively. It is concluded that the profiling system requires minimalistic inputs and provides accurate energy performance assessment of a given building.

HEALTHCARE APPLICATIONS / CHARLESTON C

Innovative Simulation Uses in Health Care

James Benneyan (Healthcare Systems Engineering Institute)

A Model Based Simulation Toolkit for Evaluating Renal Replacement Policies / Bilge Celik and Pieter M. E. Van Gorp (TU/e); Andre C. J. Snoeck (TU/e, MIT Center for Transportation and Logistics); and Remi C. van Riet, Peter J. de Winter, and Anna Wilbik (TU/e)

Renal failure concerns progressive loss of kidney function. Renal Replacement therapy (RRT) is a costly, long-running process that includes several decision points in different stages. Small changes in the protocol can impact significantly the expenditures and healthcare outcomes. Unfortunately, policy makers have very little support for benchmarking improvement alternatives. The existing models are designed to fit certain applications with preset parameters and design choices which do not match with the requirements of a policy analysis. A generic approach is required to analyze the effects of different design options adjustable to finer scales. To remedy this, this paper describes a novel toolkit for evaluating renal replacement policies, containing a parametrized colored Petri-Net which can be configured for the specifics of local settings. The model is made available for open access to overcome the non-replicability issue of existing models.

Using Simulation to Study the Impact of Racial Demographics on Blood Transfusion Allocation Policies / Marie Kahara and Jamol Pender (Cornell University)

Managing the supply and demand of blood for transfusions is a complicated problem that many hospitals encounter since the blood supply is dependent on donations while the demand is not. Moreover, recent research also shows

that transfusing older blood into patients may lead to increased mortality. This raises the issue of whether transfusing fresher blood can be achieved without jeopardizing blood availability. In this paper, we build a simulation model to study the impact of racial and ethnic diversity in combination with a blood allocation threshold. We show that for many diverse cities like New York City that the increased diversity of the population can lead to a large mismatch between blood supply and demand.

Simulation of an Active Ankle Prosthesis of One Degree of Freedom / Luis Alfredo Calle and Paúl Andrés Chacón (Universidad Politécnica Salesiana), Juan Carlos Vidal (Universidad de Cuenca), and Gabriela Lissette Carrión and Julio Cesar Zambrano (Universidad Politécnica Salesiana)

In this paper is presented the design of an active ankle prosthesis with a single degree of freedom (DoF) actuated by a linear actuator. The analysis is focused in the plantar base that shall allow the impacts absorption in gait cycle with the aim to replace the human lower limb of a person who has suffered ankle amputation. For the design it has been simulated the natural motion of a human ankle which trajectory is known for previous studies based in a biomechanical analysis of the same. For the static structural analysis has been used finite elements software ANSYS, obtaining data of stress, deformation and security factor which allow choose and couple properly the ideal linear actuator for the kind of patient and, the properly thickness of the plantar base with which the prosthesis will be built to avoid mechanic failures.

LOGISTICS, SCM, TRANSPORTATION / CHARLESTON E

Simulation Application for Container Terminals
Elizabeth R. Rasnick (Georgia Southern University)

Using Simulation and Emulation Throughout the Life Cycle of a Container Terminal / Csaba Attila Boer and Yvo A. Saanen (TBA B.V.)

The life cycle of a container terminal includes four important life stages: design, implementation, operation and optimization. In order to accomplish one of these stages it is crucial to use the appropriate approaches and tools. Two essential ingredients that help to accomplish the life stages of container terminal are simulation and emulation. In this paper the reader is guided through the maturity process of the container terminal, presenting the simulation and emulation approaches and tools applied to support each life stage.

A Simulation Model for Designing Straddle Carrier-based Container Terminals / Pasquale Legato and Rina Mary Mazza (University of Calabria)

Designing the storage yard in a container terminal is a major step towards efficient terminal operations. The problem may cover both long-term decisions, such as selecting the yard layout and the material handling equipment, and short-term decisions, such as assigning storage space and dispatching and routing the material handling equipment. We present a discrete-event simulation model to investigate the best yard layout in terms of block position, number and capacity in a straddle carrier-based transshipment hub bearing a perpendicular yard layout. The simulation model is highly detailed and it captures the blocking, locking and further waiting conditions occurring during real-time operations. Numerical experiments carried out for a real container terminal show how the model may easily support the operations manager in choosing the block design that minimizes the waiting times of straddle carriers and the makespan of the integrated container discharge/loading process.

A Modularized Simulation for Traffic Network in Container Terminals via Network of Servers with Dynamic Rates / Chenhao Zhou (National University of Singapore); Haobin Li (Institute of High Performance Computing, A*STAR Singapore); and Loo Hay Lee and Ek Peng Chew (National University of Singapore)

There are many designing factors affecting the traffic efficiency in an automated container terminal; dynamically, the traffic efficiency is also influenced by the nature of job sequence in the specific container terminal, the number of vehicles deployed, and respective yard planning strategies. Therefore, it is difficult to analyze such complexity from an analytical queuing model; however, challenges arise in the simulation study such as how to effectively model the impact of the critical designing factors as well as the decision rules. In this study, we model the traffic system as a network of servers that represent both paths and junctions, for which the service rates are dynamically adjusted according to the respec-

tive states and decision rules. The model is implemented with O2DES.Net, an open-structured and modularized modeling framework. Numerical experiments illustrate the effectiveness of developed models, with an application of the AGV network for an automated container terminal.

MASM / VERANDA E

Dispatching Applications

Lars Moench (University of Hagen)

Analyzing Different Dispatching Policies for Probability Estimation in Time Constraint Tunnels in Semiconductor Manufacturing / Alexandre Lima, Valeria Borodin, and Stephane Dauzère-Pérès (Ecole des Mines de Saint-Etienne) and Philippe Vialletelle (STMicroelectronics)

In semiconductor manufacturing, new technologies impose more and more time constraints in product routes, i.e. a maximum time between two (often non-consecutive) operations. The management of Time Constraint Tunnels (TCTs, combining multiple time constraints) in high-mix facilities is becoming more and more challenging. This paper first recalls an approach for estimating the probability that a lot at the entrance of a TCT will leave the TCT on time. This approach relies on a list scheduling algorithm using a dispatching policy with random components. Three dispatching policies are presented. Computational experiments on industrial data comparing the three dispatching policies are presented and discussed. Perspectives are drawn to extend the approach and support decision making.

Two Boundary based Dispatching Rule for On-time Delivery and Throughput of Wafer FABs with Dedication Constraints / Kang H. Cho, Yong H. Chung, and YouIn Choung (Ajou university); ByungH. Kim (VMS Solutions Co., Ltd.); and Sang C. Park (Ajou university)

This paper is to achieve the on-time delivery and throughput for a semiconductor wafer fabrication (FAB) with dedication constraint. To be successful in the globalized competition, most of the companies have applied a concept of the production target which is defined as the quantity of production to be achieved for each day. Also, it is necessary to consider natural bias that significantly affects the alignment of patterns between different photolithography steps. As the natural bias has a negative effect on the quality and yield of products, most manufacturers have applied dedication constraint. To overcome the problem, we propose the two boundary based dispatching rule with the dedication constraint. The simulation model based on MIMAC6 was developed to prove the performance of this proposed dispatching rule, and conducted a simulation by using MOZART®. The simulation results clearly show the advantages of the proposed dispatching rule over the other dispatching rules.

Simulation-based Optimization to Design Equipment Health-aware Dispatching Rules / Lorenz Reinhardt and Lars Moench (University of Hagen)

In this paper, we discuss the construction of dispatching rules for semiconductor wafer fabrication facilities (wafer fabs) that take equipment health issues into account. Monitoring the equipment health status of critical machines is important to maintain process quality and to reduce rework and scrap. Usually, there is a tradeoff between quality- and productivity-related goals in wafer fabs. Obtaining an appropriate compromise between these two objectives is addressed by considering blended dispatching rules. Simulation-based optimization based on variable neighborhood search (VNS) using a reduced simulation model of a wafer fab is applied to determine appropriate weights for the different priority indices. We demonstrate by simulation experiments that the obtained blended dispatching rule performs well compared to dispatching rules that are designed only for a single quality- or productivity-related objective.

MANUFACTURING APPLICATIONS / CHARLESTON B

Manufacturing Applications II

Anders Skoogh (Chalmers University of Technology)

Coupled Simulation of Energy and Material Flow - A Use Case In An Aluminum Foundry / Tim Peter, Lionel Reiche, Sigrid Wenzel, and Martin Fehlbier (University of Kassel)

This work presents a simulative approach to combine material flow simulation with the energy flow simulation for a foundry use case. The casting process is

strongly dependent on the conventionally true value of the temperature, and hence a high accuracy in the thermodynamic models is needed. The presented approach reaches this accuracy via the mathematical tool MATLAB. The coupled simulation of Plant Simulation and MATLAB models provides a possibility to combine a material flow simulation with a mathematical software. With the help of this tool even complex thermodynamic problems can be solved. Furthermore, this work examines different simulation scenarios and their results on the output and energy consumption of a foundry. The results show the influence of the charging intervals and the melt temperature on machine failure and hence on the casting part throughput.

Beyond Calls: Modeling The Connection Center / Paul Liston, James Byrne, Orla Keogh, and PJ Byrne (Dublin City University)

Call centers have been the subject of many simulation studies and the challenges and successes of modelling these environments have been widely published. Call centers have however evolved significantly in the last decade or so, as new communication technologies have become available, customer expectations have increased, and the value of customer experience has been recognized and prioritized. While the single-channel call centers proved complex to analyze and worthy of the advanced analytical power of simulation, the modern multi-channel connection centers bring new levels of complexity to managerial decision making. This paper presents research into the modelling challenges posed by these evolving environments and illustrates how simulation is now more beneficial than ever to organizations aiming to understand and quantify the impact of change in their customer support business.

Control and Design of the Fillet Batching Process in a Poultry Processing Plant / Kay Peeters, Tugce Martagan, and Ivo Adan (Eindhoven University of Technology) and Patrick Cruysen (Marel Poultry)

In the poultry processing industry demand and supply are still growing in volume and diversity, which requires more processing capacity, flexibility and smarter control. This paper focuses on the fillet batching process. To minimize the giveaway of fixed-weight fillet batching the right choices on layout, buffer sizes, batch sizes and batch allocation policies are of great importance. We develop a simulation model to support such decisions on design and control. The model is used (i) to determine buffer and grader sizes, (ii) to optimize batch allocation in a dedicated layout, (iii) to compare a dedicated to a flexible layout and (iv) to assess the impact of smart allocation policies. In particular we find that significant reductions in giveaway can be achieved by employing so-called index policies in a flexible layout.

MILITARY, HOMELAND SECURITY AND EMERGENCY RESPONSE / CHARLESTON A

Operations Modeling

Susan M. Sanchez (Naval Postgraduate School)

A Reference Autonomous Mobility Model / Phillip Durst and Christopher Goodin (U.S. Army ERDC) and Derek Anderson and Cindy Bethel (Mississippi State University)

Mobility modeling is a critical aspect of the ground vehicle acquisition process. Mobility modeling for traditional ground vehicles is well-understood; however, mobility modeling tools for evaluating autonomous mobility are sparse. Users do not understand the performance capabilities of autonomous ground vehicles at a mission level because no mission-level mobility model exists for autonomous vehicles. Therefore, this paper proposes a Reference Autonomous Mobility Model (RAMM). The RAMM serves as the mission-level mobility modeling tool that is currently lacking in the UGV community. The RAMM is built on the framework already established by trusted mobility modeling tools to fill the current analysis gap in the autonomous vehicle acquisition cycle. This paper gives a detailed description of the RAMM along with an example applications of the RAMM for modeling autonomous mobility. Once fully developed, the RAMM could serve as an integral part in the development, testing and evaluation, and fielding of autonomous UGVs.

Simulation Based Multi-mission Cutter Scheduling Evaluation for the United States Coast Guard / Gregory Higgins (United States Coast Guard) and Sercan Demir and Nurcin Celik (University of Miami)

The United States Coast Guard (USCG) plans the world-wide operations of

its ships, referred to as cutters. Rule-based decision making mechanisms, the primary planning tools, are aimed at ensuring adequate time inport for maintenance, stand-by, and generalized assignments for at-sea deployments to geographic regions. This approach is problematic. Stochastic events are becoming increasingly costly. In 2013, Coast Guard cutters suffered nearly four times the normally allocated amount of operational days lost to unplanned repairs. Additionally, the predominant metric used by schedulers is the amount of time a cutter is focused on a single, primary mission. The reality of multi-mission operations is that unplanned emergency missions often supersede planned, routine missions. Furthermore, mission results contribute to multiple strategic goals, though to varying extents based on geographic area. We propose a comprehensive multi-mission schedule evaluation mechanism that measures productivity, given limited Coast Guard resources, across a spectrum of current and future scenarios.

Modeling Anti-Air Warfare with Discrete Event Simulation and Analyzing Naval Convoy Operations / Ali E. Opcin (Turkish Naval Forces) and Arnold H. Buss, Thomas W. Lucas, and Paul J. Sanchez (Naval Postgraduate School)

Using anti-air warfare tactics and concepts of operations, we explore the dominant factors for convoy operations. A discrete event simulation that facilitates modern analysis was built to model ships, their sensors, and their weapons. The model was used to simulate over 1.5 million naval battles in which we varied 99 input variables using a nearly orthogonal nearly balanced (NOB) Latin hypercube design of experiments. Metamodels were then constructed to study what impact the factors have on the survival of a High Value Unit, and give guidance for which factors offer the most improvement. In addition to our specific findings, this study can be used as a guide for how to conduct future analyses.

SOCIAL AND BEHAVIORAL SIMULATION / VISTAS

Social Simulation Methodologies

Cristina Ruiz-Martín (Carleton University)

The Rig: A Leadership Practice Game to Train on Debiasing Techniques / Martin Prause and Jürgen Weigand (WHU – Otto Beisheim School of Management)

Cognitive biases such as myopic problem representation, group think, the conjunction fallacy, and confirmation bias impair effective decision making. Therefore, successful leadership should be able to spot and mitigate circumstances that promote cognitive biases. To understand and experience the consequences of cognitive biases and to teach and train on adequate countermeasures (debiasing techniques), this article presents a serious game for leadership practice. In a round-based game, a group of participants works as a team to make decisions constrained by time, uncertainty, lack of information, and conflict. The game simulates the last stages of finalizing deep sea oil exploration. While the game focuses on behavioral learning outcomes, the final debriefing emphasizes emotional aspects to achieve a long-lasting learning effect. The debriefing reveals that the game is not artificial but mimics exactly the stages that led to the real catastrophe at the Deepwater Horizon rig in the Gulf of Mexico in 2010.

Dynamic Multiplex Social Network Models on Multiple Time Scales for Simulating Contact Formation and Patterns in Epidemic Spread / Günter Schneckenreither and Niki Popper (Vienna University of Technology)

This contribution presents a model for dynamic networks of physical contacts among large populations and their application for reproducing complex patterns in epidemic spread. The networks are constructed from statistical data on demography, geography, organizational structure and contact behavior. Due to the heterogeneous nature of the data and by construction, rich topological characteristics such as overlapping communities, layering along multiple dimensions and multiplex dynamics on different time scales can be observed. The generated dynamic networks can furthermore be regarded as subgraphs or derivatives of latent social networks. General results and observations form social network theory apply naturally and are used for explaining dynamic effects in epidemics. An exemplaric analysis investigates the impact of weak ties and effects of communities with decreased immunization on epidemic spread. Optimized implementation and visualization techniques turn out to be a key asset for dynamic simulation of contacts within large populations.

Evolving a Grounded Approach to Behavioral Composition / Mayuri Duggirala, Mukul Malik, Suman Kumar, and Harshal Hayatnagarkar (Tata Consultancy Services) and Vivek Balaraman (Tata Consultancy Services)

Human behaviour simulation models having cognitive, physiological and social dimensions of behaviour has been of interest for a long time. Within this landscape however work has lagged in 2 vital areas. There has not been much attention paid to models grounded in the behavioural sciences nor on techniques to create such models. In this work, we address both lacunae. We present a compositional approach to create grounded human behavioural simulation models and demonstrate its use with an example. The compositional approach has 3 components, a behavioural science element, a statistical and a computational. The behavioural component uses approaches to theory development in the behavioural sciences particularly in the realm of organizational behaviour. The statistical element derives valid chains of relations. Finally the computational element converts the base model into a simulate model. We demonstrate our approach by creating and executing a simulation model in the workplace domain.

Monday 3:30p.m.-5:00p.m.

HISTORY OF SIMULATION / TRAILS

History of the Winter Simulation Conference, II

Bruce Schmeiser (Purdue University)

History of the Winter Simulation Conference: Coming-of-Age Period (1983-1992) / Robert G. Sargent (Syracuse University)

This paper presents the history of the Winter Simulation Conference (WSC) for the time period of 1983 – 1992. This was a healthy time period for WSC as conference attendance was great, exhibits were added, proceedings became hardback, program tracks were added, the PhD. Colloquium initiated, and the Twenty-Fifth Anniversary of WSC was celebrated in 1992. This article discusses all of the accomplishments for this “Coming-of-Age Period”.

History of the Winter Simulation Conference: Period of Growth, Consolidation, and Innovation (1993-2007) / Russell R. Barton (The Pennsylvania State University), Jeffrey A. Joines (North Carolina State University), and Douglas J. Morrice (The University of Texas at Austin)

In this paper, we consider the history of the Winter Simulation Conference (WSC) from 1993–2007, a period characterized by growth, consolidation, and innovation. We examine developments in the WSC program including rapid proliferation of new tracks and mini-tracks to match the interests of WSC attendees. Our essay also considers the impact of technological advancements. With the launch of www.wintersim.org in 1995, the website soon became the main vehicle for dissemination of information to conference participants. Additionally, it enabled the development of the online paper-management system for submission, review, revision, and final delivery to the publisher of all papers in the Proceedings. The website also led to significant changes in how the Proceedings was published and archived. Lastly, we survey developments in the WSC administration concerning the WSC Board of Directors structure, conference financing, new conference venues (e.g., the decision to take the conference international), and novel collaborations.

History of the Winter Simulation Conference: Modern Period (2008–2017) / Christos Alexopoulos (Georgia Institute of Technology), Jeffrey Joines (NC State University), and Michael E. Kuhl (Rochester Institute of Technology)

In this paper we review the history of the Winter Simulation Conference (WSC) during 2008–2017, a period characterized by financial stability, continued growth, and inroads into the new age of simulation. In particular, we trace the modernization of the Conference as well as its expansion outside of the United States for the first time.

INTRODUCTORY TUTORIALS / RED ROCK G

Open Science: Approaches and Benefits for Modeling & Simulation

Stewart Robinson (Loughborough University)

Open Science: Approaches and Benefits for Modeling & Simulation / Simon J.E. Taylor, Anastasia Anagnostou, and Adedeji Fabiyi (Brunel University London); Christine Currie and Thomas Monks (University of Southampton); Roberto Barbera (Catania University); and Bruce Becker (C.S.I.R. Meraka Institute)

Open Science is the practice of making scientific research accessible to all. It promotes open access to the artefacts of research, the software, data, results and the scientific articles in which they appear, so that others can validate, use and collaborate. Open Science is also being mandated by many funding bodies. The concept of Open Science is new to many Modelling & Simulation (M&S) researchers. To introduce Open Science to our field, this paper unpacks Open Science to understand some of its approaches and benefits. Good practice in the reporting of simulation studies is discussed and the Strengthening the Reporting of Empirical Simulation Studies (STRESS) standardized checklist approach is presented. A case study shows how Digital Object Identifiers, Researcher Registries, Open Access Data Repositories and Scientific Gateways can support Open Science practices for M&S research. The article concludes with a set of guidelines for adopting Open Science for M&S.

ADVANCED TUTORIALS / VERANDA C

Simulating Networks with ns-3 and Enhancing Realism with DCE

Philip A. Wilsey (University of Cincinnati)

Simulating Networks with ns-3 and Enhancing Realism with DCE / Jared S. Ivey (Warner Robins Air Logistics Complex), Brian P. Swenson (Georgia Tech Research Institute), and George F. Riley (Georgia Institute of Technology)

Communication networks are constantly evolving with new technologies providing greater quality, resiliency, and security to the data traversing current networks. In this ever-changing field, simulation provides an avenue for examining the traffic within new or existing networks. In simulating a network, characteristics and metrics of the topology may be derived without interfering with the existing framework or incurring an immediate hardware or software cost. The popular network simulator ns-3 is an effective tool for studying these network behaviors. This talk presents an overview of ns-3, discussing its design as a discrete event network simulator and its capabilities. Code snippets will be examined, demonstrating how to configure a network topology in simulation, generate packet traffic to traverse the simulated network, visualize the network behaviors, and glean metrics from the simulation. A subproject of ns-3, Direct Code Execution (DCE), is also described, demonstrating a mechanism for deploying real-world applications within the simulation.

MODELING METHODOLOGY / RED ROCK I

The State of Innovation in Modeling and Simulation: The Last 50 Years

Fernando Barros (University of Coimbra)

The State of Innovation in Modeling and Simulation: The Last 50 Years / Osman Balci (Virginia Tech), Richard M. Fujimoto and David Goldsman (Georgia Institute of Technology), Richard E. Nance (Virginia Tech), and Bernard P. Zeigler (The University of Arizona)

Innovation in Modeling and Simulation (M&S) refers to exploiting new ideas, exploiting new technology, and employing out-of-the-box thinking, which lead to the creation of new methodologies, techniques, concepts, frameworks, and software. This paper addresses the following questions: (a) what was the state of the art in M&S 50 years ago, what is it today, how much progress has been made? (b) how much innovation in M&S has been accomplished over the last half a century? (c) what were the obstacles to innovation in M&S? (d) what are some recommendations to promote innovation in M&S? (e) what message should be sent to the funding agencies to encourage innovation in M&S?

AGENT-BASED SIMULATION / RED ROCK H

Buidling Occupancy and Crowd Simulation

Young-Jun Son (University of Arizona)

Data Assimilation With Sensor-Informed Resampling For Building Occupancy Simulation / Sanish Rai (West Virginia University Institute of Technology) and Xiaolin Hu (Georgia State University)

A building occupancy simulation and estimation simulates the dynamics of occupants and estimates the real time spatial distribution of occupants in a building. It needs a simulation model and a data assimilation algorithm that assimilates real-time sensor data into the simulation model. In our previous works, we presented a graph-based agent-oriented simulation model, and a data assimilation framework based on Sequential Monte Carlo (SMC) methods for efficient real time occupancy estimation involving a large number of occupants. As the occupancy and the building environment size increases, there is a major problem with data assimilation caused by the high dimensional system states. To address this issue, this paper presents a new sensor-informed resampling method which utilizes sensor data to improve resampling of particles. Experiment results show the new method was able to provide better estimation of the system state with a limited number of particles compared to the standard bootstrap filter.

Large-scale Distributed Agent-based Simulation for Shopping Mall and Performance Improvement with Shadow Agent Projection / Hideyuki Mizuta (IBM Japan)

In this paper, we introduce the agent-based simulation of a shopping mall with walking and purchasing behavior model and consider the performance of distributed parallel execution. To utilize the agent-based simulation for decision support, distributed parallel execution of large-scale agent-based social simulations is important for evaluating the complex behavior of a realistic number of people with acceptable performance. For this purpose, today's agent-based simulation frameworks often provide the functionality to transfer agents from one node to another. However, intelligent social agents tend to contain a large amount of data including demographics, preferences, and history. Hence, the transfer of such an agent incurs a heavy communication cost that has an adverse effect on performance. To improve the performance of distributed agent-based simulation, we introduce a shadow agent that is a lightweight entity projected among nodes with only required information such as the position and speed required to calculate interaction between agents.

Simulating Crowd Motion Using Density Estimation and Optical Flow / Di Chen and Gary Soon Tan (National University of Singapore) and Antoine Fagette and Stephen Chai (Thales Group)

Crowd simulation is often used as a crucial tool to analyse crowd behaviours. Ideally, when analysing live video streams, we would like the simulator to be able to run concurrently. However, crowd video analytics algorithms are usually not able to supply position updates in real time as there exists a noticeable time gap between two consecutive human position updates. the crucial problem is therefore on how to simulate human positions within the time gap. In this paper, a simulation framework that could approximate human displacements in a near real time manner is proposed. A framework based on OpenCV that reads video streams and runs real time simulation is implemented. As a result, amongst the crowd being tracked, we obtain near real time simulation with acceptable tracking accuracy. Lastly, this paper explains the limitation of the proposed framework.

HYBRID SIMULATION / HILLS

Methodology and Frameworks for Hybrid Simulation

Joe Viana (Akershus University Hospital)

Modeling Mixed Type Random Variables / Christopher Weld and Lawrence Leemis (The College of William and Mary)

Mixed type random variables contain both continuous and discrete components, and their role is critical in many well-studied fields. Queuing analysis, stock options, and hydrology rainfall models are among those dependent on mixed random variables to simulate event outcomes. In each of these examples, continuous positive distributions combine with a discrete spike at zero to adequately represent system uncertainty. These problems often require simulation because analytic solutions using these hybrid distributions quickly grow in complexity. Concessions are made, however, when using simulation. In addition to inherent sampling variability, perspective of discrete and continuous components is easily lost when plotting results. This paper details these challenges, and touches on the shifting line between simulations and attainable analytic results. It discusses

computational probability's potential to improve model realism and accuracy, introducing MixedAPPL software prototype, an extension of Maplesoft based APPL (A Probability Programming Language) capable of manipulating mixed type random variables.

A Cross-Paradigm Simulation Framework For Complex Logistics Systems / Thiago Brito and Rui Carlos Botter (University of Sao Paulo)

As hybrid simulation development context is a new topic with limited available applications and data, and thus still mistrusts most researches, this work proposes a methodology to combine discrete event simulation (DES) and System Dynamics (SD) paradigms on a logistics background. On the basis of knowledge induced from literature, a generic conceptual framework for hybrid simulation has been developed. The proposed framework is demonstrated using an explanatory case study comprising an user transportation mode choice. The methodology is able to create an feedback dynamic between both paradigms, ensuring advantage to hybrid methodology modeling, that is able to combine and extract the benefits from both paradigms.

A Hybrid Simulation Model of Helping Behavior / Josiah J. Green, Caroline C. Krejci, and David E. Cantor (Iowa State University)

Companies in a variety of industries rely on their employees to work together effectively in teams to achieve their objectives. However, finding ways to encourage collaborative behavior to optimize a team's performance is often challenging. In particular, managers would like to be able to increase the likelihood that team members decide to help each other, in the event of workload imbalances. In this paper, a hybrid simulation (ABM-DES) model has been developed to investigate how workers' predisposition to altruistic tendencies, an important personality factor, influences their willingness to help their co-workers on a production task. Model inputs were derived from real time laboratory experiments from which data on participants' personalities, perceptions, and decisions to help team members complete a task were captured. Simulation results suggest that the individuals with high altruism characteristics are more likely to help their co-workers.

ANALYSIS METHODOLOGY / VERANDA B

Analytics in Applicatons

Eric Applegate (Purdue University)

Surrogate Assisted Model Reduction for Stochastic Biochemical Reaction Networks / Prashant Singh and Andreas Hellander (Uppsala University)

Cellular regulatory mechanisms are typically governed by biochemical reaction networks. Discrete stochastic models are widely used in computational systems biology to analyze such networks. Often, the models involve a large number of highly uncertain parameters and many interacting chemical species. However, one is often interested in observing the output of one, or a few of the species rather than the entire network. Simulating the complete reaction network is inefficient in such cases. This paper explores the use of surrogate models to learn partial stochastic biochemical reaction networks and enable fast near-instant evaluation. The efficacy of the proposed method is demonstrated on a model from the systems biology literature.

Explorative Analysis in a Preliminary Phase of Hybrid Vehicle Design by Means of Tangible Interaction / Kresimir Matkovic (VRVis Research Center), Denis Gracanin (Virginia Tech), Mario Duras (AVL AST d.oo), and Reza Tasooji and Mohamed Handosa (Virginia Tech)

Simulation is used often in the preliminary design phase when there are fewer control parameters thus making it feasible to use tangible visual analysis. Tangible user interfaces and interactions are realized by deploying real objects representing control parameters. Those objects can be moved and rotated in order to interact with computer and direct the visual analysis. We can take advantage of new technologies, such as Microsoft HoloLens, to provide a mixed reality based system for tangible visual analysis. Instead of using generic tokens, as the current state of the art does, we use semantic representatives that can function without augmentation. We also introduce the iconic view, integrated within a coordinated multiple views tool, which depicts input parameters. The iconic view can be used as an alternative to the tangible interface for input parameter specification. The preliminary results indicate that manipulating simulation parameters in a less abstract way helps the experts.

Portfolio Risk Measurement via Stochastic Mesh / Kun Zhang, Guangwu Liu, and Shiyu Wang (City University of Hong Kong)

We propose a stochastic mesh approach to portfolio risk measurement under the nested setting in which revaluation of the portfolio value requires simulations. While stochastic mesh was originally proposed as a tool for American option pricing, we are interested in estimating via simulation the risk of the portfolio in our context. We establish the asymptotic properties of the stochastic mesh estimator for portfolio risk. In particular, we show that the estimator is asymptotically unbiased and consistent, and its mean squared error (MSE) converges to zero in a rate of γ^{-1} , where γ is the effort required to simulate the sample paths. This rate of convergence is the same as that under the non-nested setting. The proposed method allows for path dependence of financial instruments in the portfolio. Preliminary numerical experiments show that the proposed method works reasonably well.

SIMULATION OPTIMIZATION / PAVILION

Metamodel-based Simulation Optimization

Szu Hui Ng (National University of Singapore)

Computational Methods for Optimization via Simulation Using Gaussian Markov Random Fields / Mark B. Semelhago, Barry L. Nelson, and Andreas Waechter (Northwestern University) and Eunhye Song (Penn State University)

There has been recent interest, and significant success, in adapting and extending ideas from statistical learning via Gaussian process (GP) regression to optimization via simulation (OvS) problems. At the heart of all such methods is a GP representing knowledge about the objective function whose conditional distribution is updated as more of the feasible region is explored. Calculating the conditional distribution requires inverting a large, dense covariance matrix, and this is the primary bottleneck for applying GP learning to large-scale OvS problems. If the GP is a Gaussian Markov Random Field (GMRF), then the precision matrix (inverse of the covariance matrix) can be constructed to be sparse. In this paper we show how to exploit this sparse-matrix structure to extend the reach of OvS based on GMRF learning for discrete-decision-variable problems.

Enhancing Pattern Search for Global Optimization with an Additive Global and Local Gaussian Process Model / Qun Meng and Szu Hui Ng (National University of Singapore)

Optimization of complex real-time control systems often requires efficient response to any system changes over time. By combining pattern search optimization with a fast estimated Gaussian Process model, we are able to perform global optimization more efficiently for response surfaces with multiple local minima or even dramatic changes over the design space. Our approach extends the pattern search for global optimization problems by incorporating the global and local information provided by an additive global and local Gaussian Process model. We further develop a global search method to identify multiple promising local regions for parallel implementation of local pattern search. We demonstrate our methods on a standard test problem.

Trust Region Based Stochastic Optimization with Adaptive Restart: A Family of Global Optimization Algorithms / Logan M. Mathesen and Giulia Pedrielli (Arizona State University) and Szu Hui Ng (National University of Singapore)

The field of simulation optimization has seen algorithms proposed for local optimization, drawing upon different locally convergent search methods. Similarly, there are numerous global optimization algorithms with differing strategies to achieve convergence. In this paper, we look specifically into meta-model based algorithms that stochastically drive global search through an optimal sampling criteria evaluated over a constructed meta-model of the predicted response considering the uncertainty of the response. We propose Trust Region Based Optimization with Adaptive Restart (TBOAR), a family of algorithms that dynamically restarts a trust region based search method via an optimal sampling criteria derived upon a meta-model based global search approach. Additionally, we propose a new sampling criteria to reconcile undesirable adaptive restart trajectories. This paper presents preliminary results showing the advantage of the proposed approach over the benchmark Efficient Global Optimization algorithm, focusing on a deterministic black box simulator with a d -dimensional input and a one-dimensional response.

ARCHITECTURE AND CONSTRUCTION / VERANDA A

Construction Safety and Risk Analysis

Amir Behzadan (Texas A&M University)

Coupling Risk Attitude and Motion Data Mining in a Preemptive Construction Safety Framework / Khandakar M. Rashid (Arizona State University) and Songjukta Datta and Amir H. Behzadan (Texas A&M University)

Construction sites comprise constantly moving heterogeneous resources that operate in close proximity of each other. The sporadic nature of field tasks creates an accident prone physical space surrounding workers. Despite efforts to improve site safety using location-aware proximity sensing techniques, major scientific gaps still remain in reliably forecasting impending hazardous scenarios before they occur. In the research presented in this paper, spatiotemporal data of workers and site hazards is fused with a quantifiable model of an individual's attitude toward risk to generate proximity-based safety alerts in real time. In particular, a worker's risk index is formulated and coupled with robust hidden Markov model (HMM)-based trajectory prediction to approximate his/her future position, and detect imminent contact collisions. The designed methodology is explained and assessed using several experiments emulating interactions between site workers and hazards. Preliminary results demonstrate the effectiveness of the designed methods in robustly predicting potential collision events.

Acquisition and Processing of Input Data for an Object-oriented safety Risk Simulation in Building Construction / Juergen Melzner (Bauhaus-Universität Weimar)

The construction industry records the highest rate of accidents amongst all industrial sectors. Accidents occur due to shortcomings in the identification of unsafe conditions before an activity is executed. Building Information Modeling (BIM) is a promising development in the construction industry, which can be applied to considerations relating to occupational health and safety issues. Only a few research activities have earlier focused on the use of building information models to identify safety hazards. The present work deals with the integration of the processes of risk assessment in a model-based environment. Based on algorithms that have been developed, a systematic identification and categorization of hazards – based on a building model – has been devised. The hazards are specifically identified with regard to object, process, and environment, and documented in the context of an object-oriented database. This paper will show the process of input data acquisition for generating the knowledge base.

Characterization of the Underlying Mechanisms of Vulnerability in Complex Projects Using Dynamic Network Simulation / Jin Zhu and Ali Mostafavi (Texas A&M University)

The objective of this study was to investigate the underlying mechanisms of vulnerability in complex construction projects using simulation experiments. Specifically, two hypotheses related to project vulnerability were tested: (1) project schedule performance is negatively correlated with vulnerability; (2) the level of project vulnerability is positively correlated with project exposure to uncertainty and organizational complexity. In the proposed dynamic network simulation methodology, construction projects are modeled as heterogeneous meta-networks. Project vulnerability is assessed by the decrease in meta-network efficiency due to uncertainty-induced perturbations. Project schedule deviation is used as a measure for quantifying the impacts of vulnerability on project performance outcomes. The proposed simulation methodology was implemented in three case studies of real-world construction projects. Monte-Carlo simulation experiments were conducted under different simulation scenarios consisting of varying levels of uncertainty and project planning strategies to test the hypotheses.

AVIATION MODELING AND ANALYSIS / SIENA

Separation of Air Traffic

Joe Hoffman (MITRE)

Air Traffic Simulation with 4D Multi-Criteria Optimized Trajectories / Judith Rosenow and Hartmut Fricke (Technische Universität Dresden) and Michael Schultz (German Aerospace Center (DLR))

Today's aviation industry is faced with three conflicting goals: First, aeronautics already draws responsible for 2% of all anthropologically induced emissions

(IATA 2013) and the need for reducing those emissions is no point of contention anymore. Second, the irresistible growth of air traffic demand challenges both, airport operations and air traffic flow management. And third, despite all changes, the expectations of safety are constantly increasing. To account for the need of improved, safe and climate friendly aircraft operations, we present a simulation environment, that is capable of optimizing trajectories regarding multiple criteria. Therewith we show the positive impact of 4D optimized trajectories on the air traffic flow, controller's taskload and airspace complexity and emphasize the importance of an enhanced air traffic flow management considering dynamic sectorisation and air space configuration.

Potential of runway capacity enhancements without building a new runway /
Stefan Kern (German Aerospace Center)

Runway expansion planning is mainly based on specific airport studies, complicating the transfer of results to another airport. Thus a normalized airport is introduced, including a set of technologies/procedures, to investigate possibilities to gain runway capacity. The advantage of this approach is the comparability of different enhancements and understanding their effectiveness under different situations. So before establishing a new runway the current runway structure can be used more efficiently, leading to optimal solutions for individual constraints. This is shown for a set of operational enhancements like runway usage strategy or sequencing, studied under different traffic mixes as well as arrival-departure ratios. Hereby the main focus of this paper is set to dependent parallel runway configurations.

ENVIRONMENT AND SUSTAINABILITY APPLICATIONS / VERANDA D

Applications

Pau Fonseca i Casas (Universitat Politècnica de Catalunya)

An Hybrid Simulator for Managing Hydraulic Structures Operational Modes to Ensure the Safety of Territories with Complex River Basin from Flooding / Roberto Revetria (Genoa University), Olga Ivanova and Mikhail Ivanov (Bauman Moscow State Technical University), and Lorenzo Damiani (Genoa University)

The present article examines the reasons for a steady growth in the number of registered floods and demonstrates the necessity to develop strategies ensuring integrated land and water resources management. A modern methodology of developing rules for the use of reservoirs is considered, and the basic criteria are formulated, which form the basis for planning the flow out of the reservoir. The effectiveness of the hydrotechnical structures' cascade compensating management and control mode is established. The objective of developing an hybrid simulator based on the present model was set and reached. Computer simulation boundary conditions and mathematical apparatus are formulated. The developed software modules flowcharts are presented, which allows to control the water level in a reservoir and at all the subsequent river reaches depending on the predetermined hydrographs of water inflow and water pass through hydrotechnical structures. Furthermore, the given software operating principle is demonstrated.

Modeling of Land Cover Changes on Alternative Scenarios / Anton Afanasyev and Alexander Zamyatin (Tomsk State University) and Perdro Cabral (Universidade NOVA de Lisboa)

The modeling of changes in landscape cover is a task that helps to predict the development of the territory, which may be useful, for example, in planning infrastructure development (Singh et al. 2015). In practice it is also useful to consider other development scenarios of the study area. In this paper we consider the task of handling the simulation by alternative scenarios using cellular automata and Markov chains. Approach to the preparation of initial data for modeling by an alternative scenario is proposed, the conditions for the correctness of the modification are considered, and a modification algorithm is proposed that allows maintaining correctness when partial modification conditions are met. The approach is tested on the problem of land cover changes forecasting of Portugal territory in the framework of the project LANDYN.

HEALTHCARE APPLICATIONS / CHARLESTON C

Epidemics and Spread of Disease

Aineth Torres (EGADE)

Development and Application of Agent-based Disease Spread Simulation Model: The Case of Suwon, Korea / Yo-Han Kim, Hyun-Jin Jung, Yun-Bae Kim, Gi-Sun Jung, Young Kim, and Nokhaiz Tariq Khan (SungKyunKwan University) and Jin-Soo Park (Yongin University)

The spread of diseases such as the Middle East Respiratory Syndrome (MERS) and avian influenza inflicts a significant socioeconomic problem, and highlights the need for a systematic analysis of disease spread patterns. In Korea, however, most domestic research utilize equation-based approaches that treat the entire country as a single entity and thus have limited applicability. In this study, we propose an agent-based disease spread model that reflects not only the nature of the disease, but also the structural and statistical characteristics of each sub-region's population. Based on the 2010 Census data, we develop a population model of Suwon city in Korea. The spread of MERS disease and various response strategies were analyzed based on the contact network based on the socioeconomic activities of residents. The proposed model is expected to play an important role in formulation of effective disease-related policies, reflecting the mobility and socio-economic structure of today's urban society.

Modeling Approaches, Challenges, and Preliminary Results for the Opioid and Heroin Co-Epidemic Crisis / James Benneyan, Jacqueline Garrahan, Iulian Ilies, and Xiaoli Duan (Healthcare Systems Engineering Institute)

The U.S. is in the grips of a devastating opioid and heroin co-epidemic affecting nearly all socio-economic populations at great human (~7,800 new users/day) and financial (\$78.5 billion/year) costs but with no obvious solution. We describe recent work and challenges to develop, integrate, and use several analytic multi-scale simulation models of these epidemics to develop insight into the epidemic's complex underlying dynamics, generate causal hypotheses, and inform effective policy interventions. We developed preliminary agent-based, differential equation, network spread, and cellular automata models that reasonably replicate at multiple scales the past 17 years of this epidemic's growth and spread at town, county, state, and national levels. Results suggest that some current approaches are unlikely to be very effective, some in fact may worsen the epidemic, and ultimately only certain combinations and sequences of policies are likely to have value, with important implications on both model architecture and policy optimization.

An Agent-Based Model to Investigate Behavior Impacts on Vector-Borne Disease Spread / Anna Paula Galvão Scheidegger and Amarnath Banerjee (Texas A&M University)

This study aims to use agent-based simulation as a tool to illustrate the importance of human behavior in the dynamics of vector-borne disease spread. For this, a baseline compartmental model was developed and, based on it, four different scenarios considering human behavior were proposed: two assuming the whole population adopts the same behavior and two assuming each individual has his/her own behavior. Paired t-test was used to compare the proposed scenarios with the baseline, based on two output responses from the simulation experiments: total number of infected people and duration of the epidemic. Results from the data analysis indicate that behavior is an important factor and, as such, it must be further investigated and included in infectious-disease spread models to obtain more accurate results. As a final remark, we presented possible explanations to why human behavior has been neglected in many epidemiological models up to now.

LOGISTICS, SCM, TRANSPORTATION / CHARLESTON E

Simulation Applications in Warehouse Operations

Astrid Klueter (Technical University Dortmund)

The Impact of Item Weight on Travel Times in Picker-to-parts Order Picking: An Agent-based Simulation Approach / Ralf Elbert and Jan Philipp Müller (Technische Universität Darmstadt)

In picker-to-parts order picking the traveling of the order picker between the storage locations account for approximately 50 % of the overall time. Reducing travel times can therefore substantially improve the productivity. Hereby cur-

rent research has almost exclusively focused on minimizing the travel distance and assumed a constant velocity of the order picker. However transported item weight can significantly influence the velocity and consequently travel times as well. Hence the paper at hand analyzes to which extent travel times vary in dependence of item weights in the warehouse. New weight class based storage assignment policies are investigated. Their aim is to locate the items in the storage area according to their weight so that the heaviest items are collected at the end of the order picker's tours. Agent-based simulation experiments confirm that the new policies can significantly reduce travel times.

Simulation Modeling of Shuttle Vehicle-Type Mini-Load AS/RS Systems for E-Commerce Industry of Japan / Rie Gaku (St. Andrew's University) and Soemon Takakuwa (Chuo University)

Simulation models are proposed for modeling Shuttle Vehicle-type Mini-load storage and retrieval systems (SVM-AS/RSs). The SVM-AS/RS is a fast shuttle vehicle-type mini-load automated storage and retrieval system designed to provide for storage and sorting functions including inventory buffer before shipping, picking, assorting, palletizing, or merging. The systems considered in this study consist of lightweight shuttle vehicles installed on each level, storing and retrieving lifters, layer conveyors connecting lifters and shuttle vehicles, and incoming and outgoing aisle conveyors. To analyze its performance, simulation models are performed taking the relationships of the storage locations and load sequences into consideration. It is emphasized that AS/RS operations of the mini-load system can be confirmed by simulation experiments. In addition, the key performance indicators (KPIs) from the simulation analysis can be used to understand and validate its efficiency and effectiveness under different layouts.

Determination of an Empirical Model of Average Rank for Multi-deep As/rs Based on Simulation / Latefa Ghomri (Tlemcen University) and Olivier Cardin (LUNAM Université, IUT de Nantes)

We consider in this paper multi-deep automated storage/retrieval systems, where the cell capacity is strictly greater than one load. The main advantage of this class of AS/RS is a better use of space. Its main drawback is that, in order to retrieve a desired load, it is necessary to move all the loads in front of it. This is a common characteristic of all the multi-deep automated storage/retrieval systems. The number of loads to move is given by the rank of the load to retrieve. Our objective is to provide an empirical formula of the average retrieval rank in a multi-deep automated storage/retrieval system. With this formula, it is easy to deduce the mean retrieval time. This computation is based on multiple simulations of various AS/RS models and a regression on the obtained data. The particular case of the flow-rack automated storage/retrieval system will be considered to illustrate our contribution.

MASM / VERANDA E

Simulation-based Decision Support for AMHS

Jesus Jimenez (Texas State University)

Simulation Based Evaluation of Different Empty Vehicle Management Strategies with Considering Future Transport Jobs / Robert Schmalzer and Thorsten Schmidt (Technische Universität Dresden) and Matthias Schoeps, Joerg Luebke, Ralf Hupfer, and Nikolas Schlaus (GLOBALFOUNDRIES)

Even in today's semiconductor Fab the Automated Material Handling System (AMHS) is still the part one pays too little attention to. With having in mind that all the added value is done on the process tools this opinion might be comprehensible. But without the Overhead Hoist Transport (OHT) vehicles to be at the right time at the right place semiconductor manufacturing could not work efficiently. The following paper describes new empty vehicle management strategies as an important part of this on time AMHS delivery. Information about future upcoming transport jobs will be included to allocate this limited resource proactively and to achieve goals such as minimizing the tool waiting time for empty vehicles or the total number of dispatch moves. Different scenarios with changing input parameters will be tested and compared by using a simulation model which was developed with the focus of representing empty vehicle balancing functionalities.

Continuous Flow Transport Scheduling for Conveyor-Based AMHS in Wafer Fabs / Clemens Schwenke and Klaus Kabitzsch (Dresden University of Technology)

Automated material handling systems (AMHS) can greatly impact the manufacturing performance of a semiconductor fabricating facility (fab). High traffic loads within an AMHS can impede individual wafer lots so that they arrive late at their destination machines. Thus, corresponding process operations as well as dependent succeeding operations will be delayed due to the fab schedule's precedence constraints. Consequently, such transport-related delays can widely propagate throughout the overall fab schedule. In order to reduce transport-related delays before time-critical operations, novel ways of planning wafer transports have been investigated in this study. For validation, a well-known realistic representative wafer fab model has been extended with conveyor elements constituting a typical AMHS for continuous flow transport (CFT). As a result, improvements of the overall fab performance due to advanced transport scheduling methods are demonstrated and compared. Finally, the practicality of the suggested methods is discussed in the dynamic scheduling context of real fabs.

A Simulation-based Approach for an Effective Amhs Design in a Legacy Semiconductor Manufacturing Facility / Ali Ben-Salem and Claude Yugma (Ecole des Mines de Saint-Etienne (EMSE), CMP) and Emmanuel Troncet and Jacques Pinaton (STMicroelectronics Rousset)

This paper addresses the design of an Automated Material Handling System (AMHS) for wafer lots in the photolithography workshop of a 200mm wafer manufacturing facility (fab) that was not initially built to have such a system. Lots transportation has to be performed using an Overhead Hoist Transport (OHT) system that was already chosen to transport reticles in the workshop. The main objective is to propose a decision support tool to characterize the AMHS elements including lot handling, transportation as well as the storage space design. A simulation-based approach is proposed to evaluate different scenarios and propose an effective AMHS design. Experimental results based on real instances confirm the capability of the proposed AMHS design to support the workshop activity.

MANUFACTURING APPLICATIONS / CHARLESTON B

Simulation Based Optimization

Guodong Shao (National Institute of Standards and Technology)

Integrating Simulation-Based Optimization, Lean, and the Concepts of Industry 4.0 / Enrique Ruiz-Zúñiga, Matias Urenda Moris, and Anna Syberfeldt (University of Skövde)

Nowadays, due to the need of innovation and adaptation for the mass production of customized goods, many industries are struggling to compete with the manufacturing sector emerging in different countries around the world. The understanding and implementation of different improvement techniques is necessary in order to take part in the so-called fourth industrial revolution, Industry 4.0. This paper investigates how two well-known improvement approaches, namely lean and simulation-based optimization, can be combined with the concepts of Industry 4.0 to improve efficiency and avoid moving production to other countries. Going through an industrial case study, the paper discusses how such a combination could be carried out and how the different strengths of the three approaches can be utilized together. The case study focuses on how the efficiency of a production site can be increased and how Industry 4.0 can support the improvement of the internal logistics on the shop floor.

A Framework for Selecting and Evaluating Process Improvement Projects Using Simulation and Optimization Techniques / Faisal Aqlan (Penn State Behrend), Sreekanth Ramakrishnan (IBM Corporation), Lawrence Al-Fandi (American University of the Middle East), and Chanchal Saha (IBM Corporation)

Selection of process improvement initiatives can be a challenging task. Process improvement projects usually fall into the following categories: Lean, Six Sigma, Lean Six Sigma, Change Management, and Business Process Reengineering. The selection process of these projects is a multi-criteria decision making process which involves multiple conflicting objectives. In this study, we develop an optimization model to select process improvement projects taking into consideration resource availability, required skills, and budget constraints.

In addition, discrete event simulation (DES) models are developed to evaluate some of the selected projects. The DES models account for the uncertainty in the system and allow for performing scenario analysis on the selected projects. To validate the proposed approach, we provide a case study from a high-end server manufacturing environment. Results can be used to enhance the decisions on selecting process improvement projects.

Towards Adaptive Simulation-Based Optimization to Select Individual Dispatching Rules for Production Control / Mirko Kück, Eike Broda, and Michael Freitag (BIBA - Bremer Institut für Produktion und Logistik GmbH at the University of Bremen); Torsten Hildebrandt (SimPlan AG); and Enzo Morosini Frazzon (Federal University of Santa Catarina)

Due to the increasing complexity of contemporary production scheduling problems, it is generally not possible to calculate nearly optimal production schedules in an acceptable amount of time. Hence, normally, dispatching rules are used to determine the job sequences. However, the selection of suitable dispatching rules is not a trivial task and depends on the relevant key performance indicators. Moreover, the suitability of dispatching rules changes over time because of the stochastic and dynamic nature of manufacturing systems. This paper proposes an adaptive simulation-based optimization approach to select individual dispatching rules for production control. The paper's contribution is two-fold. First, it shows that the proposed approach improves the performance compared to benchmark approaches in a manufacturing scenario from semiconductor industry. Second, in order to be able to react quickly to dynamic changes, it proposes strategies for maintaining information from previously calculated solutions after a change, such as a machine breakdown, occurred.

MILITARY, HOMELAND SECURITY AND EMERGENCY RESPONSE / CHARLESTON A

Manpower and Communications

Raymond Hill (Air Force Institute of Technology)

Single and Multi-objective Parameter Estimation of a Military Personnel System via Simulation Optimization / Lee Alan Evans, Ki-Hwan G. Bae, and Arnab Roy (University of Louisville)

A discrete event simulation model is developed to represent a forced distribution performance appraisal system, incorporating the structure, system dynamics, and human behavior associated with such systems. The aim of this study is to analyze human behavior and explore a method for model validation that captures the role of subordinate seniority in the evaluation process. This study includes simulation experiments that map black-box functions representing human behavior to simulation outputs. The effectiveness of each behavior function is based on a multi-objective response function that is a sum of squared error function measuring the difference between model outputs and historical data. The results of the experiments demonstrate the utility of applying simulation optimization techniques to the model validation phase of simulation system design.

Aircrew Manpower Supply Modelling Under Change: An Agent-Based Discrete Event Simulation Approach / Vivian Nguyen, Ana Novak, Mina Shokr, and Kristan Pash (Defence Science and Technology Group)

This paper deals with manpower planning using a dynamic and interactive simulation system that is agile and adaptive to robustly accommodate change – without requiring a complete rewrite. The simulation architecture extends the current hybrid modelling paradigm, which integrates agent based (AB) constraints and controls, with a discrete event simulation (DES) methodology. This allows for a more expressive, authentic representation of both process flows and agent policies that captures the advantage of system dynamics (SD) modelling by integrating agile lever controls with response feedback. This approach is inspired by the need to develop an aircrew training pipeline simulation for the Australian Defence Force (ADF) that supports the real needs for strategic manpower planning in a context of policy and requirements change management. A case study is provided to illustrate the challenges and approach.

Simulating the Effect of Degraded Wireless Communications on Emergent Behavior / Bradley Fraser (Defence Science and Technology Group), Claudia Szabo (The University of Adelaide), and Robert Hunjet (Defence Science and Technology Group)

Most swarming algorithms require individual nodes to know the locations of their

nearest-neighbor peers. Existing work assumes that this information is abundant and readily available, however, when wireless communications are used for data exchange, issues regarding dissemination arise. These include partial or complete data loss and an increased latency, significantly affecting the quality of the delivered service. In this paper, we show through extensive experimental analysis that swarm intelligent algorithms are vulnerable to degraded communication. To show how communication is affected in a contested environment, we introduce a local interaction statistic metric to capture emergence. Our analysis using agent-based simulation characterizes the decay of inherent emergence and swarm efficiency with increasing data loss and delay.

SOCIAL AND BEHAVIORAL SIMULATION / VISTAS

Applications of Social Simulation

Martin Prause (WHU)

Worker Grouping and Assignment for Serial and Parallel Manufacturing Systems Considering Workers' Heterogeneity and Task Complexity / Yaileen M. Méndez-Vázquez and David A. Nembhard (Oregon State University)

The present study addresses the grouping-assignment problem of heterogeneous workers for serial and parallel manufacturing configurations considering the worker production rate as a function of learning by doing and knowledge transfer. A simulated experiment is presented for this end, considering the maximization of the system output as the optimization goal, and the system size and tasks heterogeneity as experimental factors. Three heuristic policies are compared based on the heterogeneity of the groups with respect to the individual knowledge transfer parameter. Research related to team formation for manufacturing systems is scarce and often does not considering workers' heterogeneity nor the knowledge transfer. The results highlight the importance of considering workers' heterogeneity for the grouping and assignment of workers. The implications of this study impact the managerial decision-making process related to the grouping and allocation of workers to tasks as part of the production planning.

Modeling the Effects of Insider Threats on Cybersecurity of Complex Systems / Teodora Baluta, Lavanya Ramapantulu, Yong Meng Teo, and Ee-Chien Chang (National University of Singapore)

With an increasing number of cybersecurity attacks due to insider threats, it is important to identify different attack mechanisms and quantify them to ease threat mitigation. We propose a discrete-event simulation model to study the impact of unintentional insider threats on the overall system security by representing time-varying human behavior using two parameters, user vulnerability and user interactions. In addition, the proposed approach determines the futuristic impact of such behavior on overall system health. We illustrate the ease of applying the proposed simulation model to explore several "what-if" analysis for an example enterprise system and derive the following useful insights, (i) user vulnerability has a bigger impact on overall system health compared to user interactions, (ii) the impact of user vulnerability depends on the system topology, and (ii) user interactions increases the overall system vulnerability due to the increase in the number of attack paths via credential leakage.

Tuesday 8:00a.m.-9:30a.m.

HISTORY OF SIMULATION / TRAILS

History of Simulation Analysis

Russell Cheng (University of Southampton)

A Concise History of Simulation Output Analysis / Christos Alexopoulos (Georgia Institute of Technology) and W. David Kelton (University of Cincinnati)

This paper offers a concise history of simulation output statistical analysis during the last six decades. Given the space limitations and historical perspective, we focus on the creation of the main concepts and methodologies that shaped the area, and proceed with a brief description of their developmental stages. We direct most of our attention to mean and quantile estimation, especially for steady-state simulations, since the bulk of the literature has been in this area, but briefly mention other topics like density estimation.

History of Seeking Better Solutions, aka Simulation Optimization / Michael Fu (University of Maryland) and Shane Henderson (Cornell University)

Simulation optimization has had a long and illustrious history closely tied with the 50 years of the Winter Simulation Conference (WSC). We touch upon the historical developments of the field, highlighting research progress and their interactions with WSC. Specific areas covered include ranking & selection methods, stochastic approximation and gradient estimation, response surface methodology, and sample average approximation. We discuss the interplay between research and practice, including software developments. We conclude with some reflections on the state of the field.

History of Improving Statistical Efficiency / Russell Barton (Pennsylvania State University); Marvin K. Nakayama (New Jersey Institute of Technology); and Lee Schruben (University of California, Berkeley)

Statistical efficiency has been a focus of research since the inception of discrete-event simulation modeling and analysis, with origins perhaps twenty years before the first Winter Simulation Conference. We review important work in the design of simulation experiments, variance reduction through dependence structures, and efficient rare-event simulation. The focus is on the early developments, although some recent innovations also receive mention.

INTRODUCTORY TUTORIALS / RED ROCK G

A Tutorial on Design of Experiments for Simulation Modeling

David Bell (Brunel University London)

A Tutorial on Design of Experiments for Simulation Modeling / Averill Law (Averill M. Law & Associates, Inc.)

Simulation models often have many input factors, and determining which ones have a significant impact on performance measures (responses) of interest can be a difficult task. The common approach of changing one factor at a time is statistically inefficient and, more importantly, is very often just incorrect, because for many models factors interact to impact on the responses. In this tutorial we present an introduction to design of experiments specifically for simulation modeling, whose major goal is to determine the important factors often with the least amount of simulating. We discuss classical experimental designs such as full factorial, fractional factorial, and central composite followed by a presentation on Latin hypercube designs, which are designed for the complex, nonlinear responses typically associated with simulation models.

ADVANCED TUTORIALS / VERANDA C

Advanced Tutorial on Microscopic Discrete Event Traffic Simulation

Philip A. Wilsey (University of Cincinnati)

Advanced Tutorial on Microscopic Discrete Event Traffic Simulation / John A. Miller (University of Georgia), Casey N. Bowman (University of North Georgia), and Hao Peng (University of Georgia)

Traffic is one of the most important aspects of modern life, both in the developed world and in the developing world. Analysis of traffic systems through modeling and simulation is an essential tool for city planners to optimize traffic

flow. Microscopic discrete–event simulation is a natural and powerful method for such analysis. Characteristics of traffic systems that need to be modeled include inter–arrival times, car–following behavior, lane–changing, turning, road structure, intersection structure, and traffic light timing. There are many challenges that must be confronted as well, including the calibration and validation of traffic models, scaling models to larger traffic systems, modeling the continuous nature of traffic in a discrete–event environment, and optimization of traffic system characteristics. An emerging challenge for traffic simulation is the incorporation of autonomous vehicles into traffic systems as not only traditional vehicles, but also as cooperative agents as well.

MODELING METHODOLOGY / VERANDA D

Simulation and Games

Rodrigo Castro (Universidad de Buenos Aires)

Warriors or Bulls – Introducing Retroactive Gambling Line Simulation / Robert Alan Bowman (Clarkson University)

Gambling lines provide a rich source of data for Monte Carlo simulations of sports seasons. Since data for complete seasons are available after the seasons are completed, we refer to such simulations as retroactive gambling line simulations. We use the motivating and expository example of comparing the performances of the 2015–16 Golden State Warriors (who won a record 73 games) and the 1995–96 Chicago Bulls (who held the previous record of 72 wins) and provide a detailed treatment of this application. The more general applicability of the approach is examined by describing the flexibility in building the models and relating this flexibility to a few specific examples. We hope this paper will seed further explorations of retroactive gambling line simulation (and settle the Warriors vs. Bulls comparison along the way).

Overcoming Challenges in Educational STEM Game Design and Development / Katherine Smith, John Shull, Yuzhong Shen, Anthony Dean, and Jennifer Michaeli (Old Dominion University)

Captivate is a mobile game for STEM in higher education. In the development of Captivate, the employment of popular game mechanics and development of a set of mathematical tools have allowed developers to overcome some of the problems commonly facing developers of educational STEM games for higher education. Game mechanics from a variety of popular games are incorporated which supports player engagement by providing a familiar narrative to each game. Additionally, mathematical tools have been developed which provide symbolic and numeric manipulation capabilities within the game. These tools allow for graphing, problem generation and display, multiple types of player input, and evaluation of player answers all to be conducted at run time. This paper details how challenges were overcome and addressed in Captivate with examples, namely display and manipulation of complex expressions and the complexity and length of problems.

An Actor-model Based Bottom-up Simulation - an Experiment on Indian Demonetisation Initiative / Souvik Barat and Vinay Kulkarni (TCS), Tony Clark (Sheffield Hallam University), and Balbir Barn (Middlesex University)

The dominance of cash–based transactions and relentless growth of a shadow economy triggered a fiscal intervention by the Indian government wherein 86% of the total cash in circulation was pulled out in a sudden announcement on November 8, 2016. This disruptive initiative resulted into prolonged cash shortages, financial inconvenience, and crisis situation to cross–section of population of the country. Overall, the initiative has faced a lot of criticism as being poorly thought through and inadequately planned. We claim that these emerging adverse conditions could have been anticipated well in advance with appropriate experimental setup. We further claim that the efficacy of possible courses of actions for managing critical situations, and probable consequences of the courses of action could have been estimated in a laboratory setting. This paper justifies our claims with an experimental setup relying on what–if analysis using an actor–based bottom up simulation approach.

MODELING METHODOLOGY / RED ROCK I

Simulation and Synthetic Biology

Richard Fujimoto (Georgia Institute of Technology)

Provenance in Modeling and Simulation Studies – Bridging Gaps / Andreas Ruschinski and Adelinde Uhrmacher (University of Rostock)

Simulation studies are intricate processes that require interweaving model refinement and executing diverse experiments. Simulation models and data are the result of complex and interactive model and data generating processes. Information about these processes are required to assess the quality of simulation products. Capturing provenance, i.e., information about how a product has been generated, is a major concern both for assessing and reproducing scientific experiments. For parts of a simulation study, support for capturing and managing provenance is available. However, still gaps exist, e.g., how simulation models have been generated and to look therefore beyond individual simulation experiments and even simulation studies. To bridge those gaps it will be central to exploit, refine, and combine diverse methods effectively, as we demonstrate on a concrete case study and its provenance model.

A Brief History of COMBINE / Chris J. Myers (University of Utah), Gary Bader (University of Toronto), Padraig Gleeson (University College London), Martin Golebiewski (HITS gGmbH), Michael Hucka (California Institute of Technology), Nicolas Le Novère (The Babraham Institute), David Nickerson (University of Auckland), Falk Schreiber (University of Konstanz), and Dagmar Waltemath (University of Rostock)

Standards for data exchange are critical to the development of any field. They enable researchers and practitioners to exchange information reliably, to apply a variety of tools to their problems, and to reproduce scientific results. Over the past two decades, a range of standards have been developed to facilitate the exchange and reuse of information in the domain of representation and modeling of biological systems. These standards are complementary, so the interactions between their developers increased over time. By the end of the last decade, the community of researchers decided that more interoperability is required between the standards, and that common development is needed to make better use of effort, time, and money devoted to this activity. The COmputational MOdeling in Biology Network (COMBINE) was created to enable the sharing of resources, tools, and other infrastructure. This paper provides a brief history of this endeavor and the challenges that remain.

DiSH Simulator: Capturing Dynamics of Cellular Signaling with Heterogeneous Knowledge / Khaled Sayed (University of Pittsburgh), Yu-Hsin Kuo and Anuva Kulkarni (Carnegie Mellon University), and Natasa Miskov-Zivanov (University of Pittsburgh)

In this paper, we present DiSH, a simulator for large discrete models of biological signal transduction pathways, capable of simulating networks with multi-valued elements in both deterministic and stochastic manner. The simulator incorporates the timing of molecular reactions, which are often not synchronized and occur in random order, and it also takes into account the difference between slow and fast reactions. DiSH also allows for changes in conditions during simulations, combined deterministic and stochastic changes, and it uses the concept of delays in models, similar to delays in digital circuits. DiSH is publicly available and has been used to study intra- and inter-cellular models of several diseases. It is also being used as part of a larger architecture including natural language processing tools that read biological literature, automated model assembly tools, and formal model analysis tools.

AGENT-BASED SIMULATION / RED ROCK H

Agent-Based Simulation of Financial Markets

Ashkan Negahban (Penn State University)

Towards a Model of the U.S. Stock Market: How Important is the Securities Information Processor? / Brian F. Tivnan, Matthew Koehler, David Slater, and Jason Veneman (MITRE) and Brendan F. Tivnan (University of Vermont)

Both the scientific community and the popular press have paid much attention to the speed of the Securities Information Processor – the data feed consolidating all trades and quotes across the US stock market. Rather than the speed of the Securities Information Processor, or SIP, we focus here on its importance

to efficient, price discovery. Via extensions to a previous market model, we experiment with four different coupling mechanisms which operate across the US stock market. Of the four, we find that the SIP contributes most to efficient price discovery.

StockYard: A Discrete Event-Based Stock Market Exchange Simulator / Jianling Wang, Vivek George, and Tucker Balch (Georgia Institute of Technology) and Maria Hybinette (The University of Georgia)

We describe an agent-based stock market simulator built using an asynchronous discrete event simulation framework. The simulator is unique in that it's driven by real-world financial algorithms and protocols; and it's open source. It utilizes an order book bid and ask matching model, and real-world exchange protocols. Our simulation is based on multiple agents interacting through an exchange agent. This method is distinct from those that utilize historical pricing data. Order book execution supports a more realistic interaction between agents. Pricing in our model arises from the dynamics of matching orders in the order book. Our simulator enables the study of market dynamics, and trading strategies using real-world exchange protocols. We present our design and implementation of a market simulator and discuss our initial results using the message protocols defined by NASDAQ: OUCH and ITCH. Our initial results demonstrate StockYard's capability and efficiency in simulating markets with realistic trade volumes.

An Agent-Based Study of Herding Relationships with Financial Markets Phenomena / Yasaman Kamyab Hessary and Mirsad Hadzikadic (University of North Carolina at Charlotte)

In this paper, an agent based model of stock market is developed. All agents fall under three general trading systems: fundamentalists, optimists and pessimists, while having different beliefs within each category. The model stresses interaction and learning among adaptive agents, which causes macroscopic properties to emerge in the market. The generated time series revealed that the model was able to reproduce some of the key stylized facts observed in actual financial time series and was consistent with empirical observations. Herding is one of the important emergent properties of financial markets, often leading to the creation of speculative bubbles that make markets unstable and prone to crashes. Using this validated framework, the necessary infrastructure is provided to explore the relationships of different market properties with this phenomenon. The study suggests that herding has significant causal relationship with volatility in the market, and vice versa.

HYBRID SIMULATION / HILLS

Panel on Hybrid Simulation

Navonil Mustafee (University of Exeter)

Purpose and Benefits of Hybrid Simulation: Contributing to the Convergence of Its Definition / Navonil Mustafee (University of Exeter), Sally Brailsford (University of Southampton), Anatoli Djanatliev (University of Erlangen-Nuremberg), Tillal Eldabi (Brunel University London), Martin Kunc (University of Warwick), and Andreas Tolk (The MITRE Corporation)

There is a growing trend in the number of M&S studies that report on the use of Hybrid Simulation. However, the meaning and the usage of the term varies considerably. Indeed, the hybrid simulation panel during last year's conference (WSC2016) laid bare the strong views, from the panelists and audience alike, as to what constitutes a hybrid model and what is new? The ensuing debate set the scene for this year's paper, in which we discuss the various perspectives on hybrid simulation by focusing on three aspects: its definition, its purpose and its benefits. We hope this paper will pave the way for further studies on this subject, with the objective of achieving a convergence of the definition of hybrid simulation.

ANALYSIS METHODOLOGY / VERANDA B

Factors and Sampling

Kyle Cooper (Tata Consultancy Services, Purdue University)

Improving Prediction from Stochastic Simulation via Model Discrepancy Learning / Henry Lam, Matthew Plumlee, and Xinyu Zhang (University of Michigan)

Stochastic simulation is an indispensable tool in operations and management applications. However, simulation models are only approximations to reality, and typically bear discrepancies with the generating processes of real output data. We investigate a framework to statistically learn these discrepancies under the presence of data on past implemented system configurations, which allows us to improve prediction using simulation models. We focus on the case of general continuous output data that generalizes previous work. Our approach utilizes (a combination of) regression analysis and optimization formulations constrained on suitable summary statistics. We demonstrate our approach with a numerical example.

Controlled Morris Method: A New Distribution-Free Sequential Testing Procedure for Factor Screening / Wen Shi (Hubei University of Economics) and Xi Chen (Virginia Tech)

Morris's elementary effects method (MM) has been known as a model-free factor screening approach especially well-suited when the number of factors is large or when the computer model is computationally expensive to run. In this paper, we propose the controlled Morris method (CMM) that acts in a sequential manner to keep the computational effort down to a minimum. The sequential probability ratio test-based multiple testing procedure adopted by CMM enables to identify the factors with significant main and/or interaction effects while controlling Type I and Type II familywise error rates at desired levels. A numerical example is provided to demonstrate the efficacy and efficiency of CMM.

Optimizing the Design of a Latin Hypercube Sampling Estimator / Alexander J. Zolan and John J. Hasenbein (University of Texas at Austin) and David P. Morton (Northwestern University)

Stratified sampling and Latin hypercube sampling (LHS) reduce variance, relative to naive Monte Carlo sampling, by partitioning the support of a random vector into strata. When creating these estimators, we must determine: (i) the number of strata; and, (ii) the partition that defines the strata. In this paper, we address the second point by formulating a nonlinear optimization model that designs the strata to yield a minimum-variance stratified sampling estimator. Under a discrete set of candidate boundary points, the optimization model can be solved via dynamic programming. We extend this technique to LHS, using an approximation of estimator variance to obtain strata for the domain of a multivariate function. Empirical results show significant variance reduction compared to using equal-probability strata for LHS or naive Monte Carlo sampling.

SIMULATION OPTIMIZATION / PAVILION

Ranking and Selection I

Loo Hay Lee (National University of Singapore)

A Multi-objective Perspective on Robust Ranking and Selection / Weizhi Liu (National University of Singapore), Siyang Gao (City University of Hong Kong), and Loo Hay Lee (National University of Singapore)

In this study, we consider the robust Ranking and Selection problems with input uncertainty. Instead of adopting the minimax analysis in the classical robust optimization, we propose a novel method to approach this problem from the perspective of multi-objective optimization and Pareto optimality. More specifically, the performances of each design under various scenarios are reformulated as multiple objectives, and in this case, robust Ranking and Selection becomes a multi-objective Ranking and Selection. In order to determine the number of simulation replications to various scenarios of each design, a bi-level convex optimization is formulated by maximizing the surrogate of the large deviation rate function of the probability of false selection. Numerical results show the efficiency of the proposed procedure (PR-OCBA) compared with other methods.

Optimal Computing Budget Allocation via Sampling based Unbiased Approximation / Xiao Jin (National University of Singapore); Haobin Li (Institute of High Performance Computing, A*STAR Singapore); and Loo Hay Lee and Ek Peng Chew (National University of Singapore)

In a Ranking and Selection problem, the objective of allocation efficiency is vital in deriving the rule. However, most of these objectives do not have a close form. Due to the high cost of a direct approximation, several cheap but biased substitutes were applied to simplify the problem. This simplification however could potentially affect the optimality of original problem and therefore influence

its finite performance. Fortunately, due to the increasing accessibility of parallel hardware (e.g. GPU), a direct approximation is becoming more tractable. Thus, we want to test the performance of an allocation rule based on an unbiased and direct approximation, expecting an acceleration on the performance. In this paper, we target on one of the popular objective, the Possibility of Correct Selection (PCS). Numerical experiments were done, showing a considerable improvement in finite performance of our algorithm comparing to a traditional one.

Ranking and Selection with Covariates / Haihui Shen and Liu Jeff Hong (City University of Hong Kong) and Xiaowei Zhang (The Hong Kong University of Science and Technology)

We consider a new ranking and selection problem in which the performance of each alternative depends on some observable random covariates. The best alternative is thus not constant but depends on the values of the covariates. Assuming a linear model that relates the mean performance of an alternative and the covariates, we design selection procedures producing policies that represent the best alternative as a function in the covariates. We prove that the selection procedures can provide certain statistical guarantee, which is defined via a nontrivial generalization of the concept of probability of correct selection that is widely used in the conventional ranking and selection setting.

ARCHITECTURE AND CONSTRUCTION / VERANDA A

Integrating Sensor Data in Construction Simulation

Cheng Zhang (Xi'an Jiaotong-Liverpool University)

Human Activity Recognition and Mobile Sensing for Construction Simulation / Nipun D. Nath, Prabhat Shrestha, and Amir H. Behzadan (Texas A&M University)

Construction industry has been constantly lagging behind in terms of efficiency and productivity growth. Simulation modeling can be used to improve the productivity of construction workflow processes through modeling uncertainties and stochastic events that may negatively impact project cost and schedule. In the research presented in this paper, mobile sensors coupled with machine learning techniques are used for ubiquitous data collection and human activity recognition (HAR), which will constitute the key input parameters of process simulation modeling. To assess the designed methodology, an experiment is carried out which replicates a warehouse quality control operation. Smartphones mounted on human bodies are used to collect multi-modal time-motion data. Support vector machine (SVM) is then applied to classify workers' and inspectors' activities, and activity durations are subsequently extracted. Finally, a simulation model is built using the output of the HAR phase and rigorously validated and used to analyze workflow processes, productivity, and bottlenecks.

An Evolutionary Method to Refine Imperfect Sensor Data for Construction Simulation / Prabhat Shrestha and Amir Behzadan (Texas A&M University)

Construction simulation is used to analyze uncertainties inherent to project activities and variations in work packages. However, existing simulation systems often fail to meaningfully contribute to the decision-making process due to their inability to evolve with changing project conditions. Equipping simulation models with sensing and reality capture technologies has been investigated as possible remedies to this problem. This, however, requires meticulous effort to procure, set up, operate, synchronize, and calibrate peripheral devices for data collection, transmission, and mining. Furthermore, sensor readings are often noisy and imperfect. The chaos theory explains how small variations in sensor readings used as simulation model input can lead to relatively large volatility in the output even in simple linear systems. This paper investigates a scientific methodology for generating more stable simulation models using an evolutionary algorithm that produces clean datasets by processing and significantly reducing noise in imperfect data obtained from consumer-grade sensors.

Construction Objects Recognition in Framework of Cps / Yaseen Srewil and Raimar Scherer (TU Dresden)

Recent breakthroughs in BIM and ADC technologies promise innovative solutions to bridge the information gaps between the digital models and real construction site. These solutions promote the collaboration between digital, spatial and physical construction. Cyber-physical systems offer a tight integration between real physical and virtual "cyber" models. This collaborative approach supports the digital transformation in construction domain. A cyber-physical framework

is proposed to provide consistent relationships and allow bidirectional data flow. In the framework the recognition of objects successes by linking physical objects to the digital product models using RFID. Next, these objects are equipped with global positions data and pinned to semantic and functional enrichment construction places. The results are objects at a level of “smartness” with enhanced digital capabilities and the ability of context-awareness. The cyber-physical objects are embedded in the process models in order to support tracking activities and facilitate process monitoring and control close to real-time.

AVIATION MODELING AND ANALYSIS / SIENA

Air Traffic Flow Management

Joe Hoffman (MITRE)

Building an Integrated Simulation Environment for Modeling Traffic Management Interactions / Shin-Lai Alex Tien, Huina Gao, David Bodoh, and James DeArmon (The MITRE Corporation)

The Federal Aviation Administration is funding and encouraging new concepts for improving air traffic flow management (TFM) decision-making. The resulting automation capabilities will need to be operationally integrated into the existing air traffic management system. Understanding how a new capability will interact with existing system components is challenging because of the range of possible real-world situations. Although there are fast-time traffic simulation tools available for modeling the impact of TFM actions, they are often developed as stand-alone tools, which are not extensible to work with other external capabilities for conducting integration studies or quantifying benefits. To address this gap, we have built a fast-time, distributed simulation platform integrating state-of-the-art traffic simulator and allows the plug-in of advanced TFM prototypes so their interactions can be studied. This paper discusses the requirements and the necessary components for building this platform and then use a TFM integration case study to demonstrate its utility.

A Down to Earth Solution: Applying a Robust Simulation-Optimization Approach to Resolve Aviation Problems / Paolo Scala and Miguel Mujica (Amsterdam University of Applied Sciences) and Daniel Delahaye (Ecole Nationale de l'Aviation Civile)

This paper deals with the improvement of the robustness of heuristic solutions for aviation systems affected by uncertainty when the resolution of conflicts is implemented. A framework that includes the use of optimization and simulation is described which in turn generates pseudo-optimal schedules. The initial solution is progressively improved by iteratively evaluating the uncertainty in the generated solutions and calibrating in accordance with the objective function. Simulation is used for testing the feasibility of a solution generated by an optimization algorithm in an environment characterized by uncertainty. The results show that the methodology is able to improve solutions for the scenarios with uncertainty, thus making them excellent candidates for being implemented in real environments.

Using Fast-Time Simulation to Assess Weather Forecast Accuracy Requirements for Air Traffic Flow Management / Alexander Klein (AvMet Applications, Inc.)

We present the concept and initial results of using fast-time air traffic simulation modeling to assess requirements for convective weather forecast accuracy from Traffic Flow Management (TFM) standpoint. For strategic TFM applications, such requirements can be relaxed compared with tactical weather avoidance. A gradual increase in forecast error does not necessarily cause gradual changes in operational costs associated with a given TFM action which was implemented based on that forecast. Modest inaccuracies in forecast may not require adjustments to TFM actions; but when the discrepancy between forecast and actual weather exceeds a certain threshold, it may prompt a different TFM strategy to be initiated vs. an optimal one based on the actual weather. This, in turn, may cause a significant increase in operational costs. This paper demonstrates how such thresholds, indicative of forecast accuracy requirements for TFM, can be determined using parametric forecast accuracy changes in a series of simulations.

HEALTHCARE APPLICATIONS / CHARLESTON C

Data Analysis in Health Care Simulation

Joseph K. Agor (North Carolina State University)

Hybrid Research Simulation Modeling for Making Decisions on Sample Size and Power of Randomized Clinical Trials Considering Expected Net Benefits /

Ismail Abbas (Universidad Politecnica de Cataluña)

This paper presents a framework aimed at making decisions on sample size and power that optimize expected net benefits of clinical trials that incorporate health and cost variables. Two-stages standard modeling and simulation was developed. The hybrid framework was populated with prior information on benefits of a clinical trial that compare magnetic resonance imaging vs. computerized axial tomography in a trial of acute ischemic stroke diagnostic, combined with an assumption on willingness to pay per health gain, correlated distributions, exclusivity and per patient-time cost. As results, an estimated optimal expected net benefits of €3.8M at optimal power of 34% and sample size of 1800 were calculated. Emphasis on main and sensitivity analysis results are also presented.

Hybrid, Composable Approach to Simulations in Healthcare Operations and Management / Jayanth Raghothama, Hamza Hanchi, and Sebastiaan Meijer (KTH Royal Institute of Technology)

Simulation has been used for modeling in healthcare for many decades. Ranging from the modeling of physiological processes to group dynamics to the modeling of strategic and system-wide models of healthcare provision, simulation promises to be an effective approach to analyze healthcare operations. Effective application of simulations in healthcare operations requires that simulation deal with wide variability and unpredictability in workflow processes, the complexity of healthcare organizations and enables the participation of human experts in the modeling and operations processes. In this paper, based on requirements drawn from a participatory simulation with healthcare practitioners, we define a hybrid, composable approach to healthcare simulations. Both the participatory simulation and the composable simulation are applied in the context of the New Karolinska Solna hospital in Sweden, a highly specialized new hospital. Results point to the need to accounting for variability in workflow processes and integration with existing IT infrastructure in hospitals.

Data-Driven Simulation for Healthcare Facility Utilization Modeling and Evaluation / Xuxue Sun (University of South Florida); Chao Meng (Valdosta State University); Nan Kong (Purdue University); and Hongdao Meng, Kathryn Hyer, and Mingyang Li (University of South Florida)

Utilization evaluation for healthcare facilities such as hospitals and nursing homes is crucial for providing high quality healthcare services in various communities. In this paper, a data-driven simulation framework integrating statistical modeling and agent-based simulation (ABS) is proposed to evaluate the utilization of various healthcare facilities. A Bayesian modeling approach is proposed to model the relationship between heterogeneous individuals' characteristics and time to readmission in the hospital and nursing home. An ABS model is developed to model the dynamically changing health conditions of individuals and readmission/discharge events. The individuals are modeled as agents in the ABS model, and their time to readmission and length of stay are driven by the developed Bayesian individualized models. An application based on Florida's Medicare and Medicaid claims data demonstrates that the proposed framework can effectively evaluate the healthcare facility utilization under various scenarios.

LOGISTICS, SCM, TRANSPORTATION / CHARLESTON E

Simheuristics for Logistics, SCM and Transportation (1)

Angel A. Juan (IN3-Open University of Catalonia)

A Visualization Tool Based on Traffic Simulation for the Analysis and Evaluation of Smart City Policies, Innovative Vehicles and Mobility Concepts /

Lidia Montero and M^a Paz Linares (Universitat Politècnica de Catalunya); Josep Casanovas-Garcia (Universitat Politècnica de Catalunya, Barcelona Supercomputing Center); and Oriol Serch (Universitat Politècnica de Catalunya)

The CitScale tool is a software platform for visualizing, analyzing and comparing the impacts of smart city policies based on innovative mobility concepts in urban areas. It places emphasis on new automotive vehicles aimed at reducing

traffic or environmental impacts. This paper introduces this traffic simulation-based tool, and two case studies developed for different scenarios in Barcelona City are briefly presented to demonstrate the capabilities of the tool when it is combined with microscopic traffic simulation software. The first case presents an extensive evaluation of new innovative vehicles (electric vehicles, bikes and three-wheeled scooters) and mobility concepts (trip-sharing). In the second one, data provided by connected cars is analyzed in order to compare different developed navigation strategies and how they affect the city. Finally, some of the obtained results from both cases are concisely presented in order to show the potential of the proposed tool.

A Simheuristic Approach for the Stochastic Team Orienteering Problem / Javier Panadero (Open University of Catalonia), Jesica de Armas (Universitat Pompeu Fabra), Christine S.M. Currie (University of Southampton), and Angel A. Juan (Open University of Catalonia)

The team orienteering problem is a variant of the well-known vehicle routing problem in which a set of vehicle tours are constructed in such a way that: (i) the total collected reward received from visiting a subset of customers is maximized; and (ii) the length of each vehicle tour is restricted by a pre-specified limit. While most existing works refer to the deterministic version of the problem and focus on maximizing total reward, some degree of uncertainty (e.g., in customers' service times or in travel times) should be expected in real-life applications. Accordingly, this paper proposes a simheuristic algorithm for solving the stochastic team orienteering problem, where goals other than maximizing the expected reward need to be considered. A series of numerical experiments contribute to illustrate the potential of our approach, which integrates Monte Carlo simulation inside a metaheuristic framework.

A Heuristic Simulation-based Framework to Improve the Scheduling of Blocks Assembly and the Production Process in Shipbuilding / Natalia Basán and Victoria Achkar (INTEC (UNL – CONICET)), Alejandro García-del-Valle (University of A Coruña and UMI Navantia-UDC), and Carlos Méndez (INTEC (UNL – CONICET))

The strong global competition in the shipbuilding market forces the shipyards to focus their efforts in optimizing their system resources. Therefore, the development of efficient medium and short-term operations strategies in the shipyard block assembly process is becoming a potential tool to be more competitive. This paper introduces a heuristic simulation-based approach to address the scheduling problem for shipbuilding in a system of multi-stage production of a real world case. The main goal is to minimize the total production, assembly and waiting time of the shipbuilding process (makespan) applying different types of heuristics rules in an advanced simulation framework. The proposed simulation model allows evaluating a large amount of blocks and sub-blocks, while satisfying a large set of hard constraints. The results are generated by using data from a real shipyard. Uncertain alternative scenarios are tested and computational experiences are deeply analyzed.

MASM / VERANDA E

Simulation Modeling Issues

Thomas Ponsignon (Infineon Technologies AG)

Towards a New Simulation Testbed for Semiconductor Manufacturing / Michael Hassoun (Ariel University) and Adar Kalir (Ben-Gurion University)

We propose the creation of a new set of fab simulation testbeds. Extensions and additional features, not considered in the original MIMAC datasets, shall be incorporated in these new testbeds, thus allowing researchers to evaluate new methodologies with the same frame of reference. To do this, we surveyed the literature and mapped the pertinent research efforts of the past two decades. In this paper, we discuss in detail the various aspects of the new testbeds, in order to receive feedback from the simulation community on the importance of inclusion of some of the items in question; and the verification of the required inclusion of other items. Given the feedback, we aim to generate these testbeds within a year to serve as the new frame of reference for the benefit of the entire semiconductor manufacturing simulation community.

Test Problems, Reference Models and Fab Simulation / Po-Chen Lin and Leon McGinnis (Georgia Institute of Technology)

Semiconductor fabs are among the world's most expensive factories, and pres-

ent some of the most interesting manufacturing planning and control problems. It's not a surprise that simulation is the workhorse analysis methodology, both in practice and in research. Over the past thirty years, a number of "standard" wafer fab test problems have been published to provide a common basis for comparing proposed planning and control policies and algorithms. We present a reference model, expressed in an analysis application agnostic language, OMG SysML™, that can be used to specify any of these test problems. We then show how this reference model also can be used to automate the generation of analysis models for one particular simulation solver, and argue for the use of parametric problem generators as a way to more fully explore planning and control methods.

An Easy Approach of Extending a Short Term Simulation Model for Long Term Forecast in Semiconductor Industry / Marcin Mosinski and Tobias Weissgaerber (Robert Bosch GmbH), Soo Leen Low and Boon Ping Gan (D-SIMLAB Technologies Pte Ltd), and Patrick Preuss (D-SIMLAB Technologies GmbH)

The operational decision making in the BOSCH's 200mm wafer fabrication facility has been guided by short term simulation forecasts. The forecasts provides the capability of identifying daily bottlenecks, forecasting daily fab outs, optimizing the preventive maintenance plans and personal resource planning. Now there is a pressing need to extend the forecast time horizon to several months for making decisions such as analyzing different ramp up scenarios, evaluating the impact of dispatch rules, identifying bottlenecks for capital investment, etc. As the short term model has achieved forecast accuracy of above 90%, it is used as the basis to generate the long term model. In this paper, we discuss the key issues associated with this model generation process. These issues are: process flows compression, flexible equipment dedications, model warm-up, wafer start generation, and future fab capacity changes. Our approach enables us to use the same model generation framework for both models.

MANUFACTURING APPLICATIONS / CHARLESTON B

Simulation Based Planning

Thomas Felberbauer (St. Pölten University of Applied Sciences)

Application of a Multi-Level Simulation Model for Aggregate and Detailed Planning in Shipbuilding / María del Mar Cebral-Fernández, Marcos Rouco-Couzo, Marta Quiroga Pazos, Diego Crespo-Pereira, and Alejandro García del Valle (University of A Coruña) and Rafael Morgade Abeal (Navantia Ferrol)

Shipbuilding is one of the most complex manufacturing processes due to the high number and diversity of elements involved throughout the production process. Particularly challenging is the production of singular vessels, such as frigates, where effective planning becomes crucial for delivering the vessel on schedule due to the uniqueness of the product and the lack of historical data of previous equivalent constructions associated to this singularity. In this study, an ongoing simulation-based model that minimizes the uncertainties of the shipbuilding process is presented. Using the Discrete Event Simulation software ExtendSim, three real case studies are presented for the model validation. The objective is to obtain a multi-level model that can be used not only at early stages of the project, when detailed specifications are yet unavailable, but also at later stages, when design is well advanced and extensive data become accessible.

Simulation Based Manufacturing System Improvement Focusing on Capacity and MRP Decisions – a Practical Case from Mechanical Engineering / Andreas J. Peirleitner and Klaus Altendorfer (University of Applied Sciences Upper Austria) and Thomas Felberbauer (St. Pölten University of Applied Sciences)

In this paper a practical case from an Austrian mechanical engineering company is presented. Simulation based manufacturing system improvement is applied to their component manufacturing plant. Based on the high number of items in the real case, a method for reduction of simulation model complexity applying item aggregation is developed in this paper. In the first improvement step, strategic capacity investment decisions are supported with the use of simulation. In the second step, a MRP planning parameter optimization is performed to improve service level and inventory. Additionally, the effect of capacity related decisions concerning setup time reduction and load-dependent outsourcing is evaluated. The results of this simulation study show that service level and inventory can be significantly improved by optimization of planning parameters and reduction of setup times. In addition, the study shows that load-dependent outsourcing is a viable alternative to capacity investment.

Simulation Based Approach to Calculate Utilization Limits in Opto Semiconductor Frontends / Falk Stefan Pappert (Universität der Bundeswehr), Fabian Suhrke and Jonas Mager (OSRAM Opto Semiconductors GmbH), and Oliver Rose (Universität der Bundeswehr)

Capacity planning is a crucial task for economically sound production. Especially in semiconductor manufacturing, as equipment is expensive and production complex. An important part of valid capacity planning is a good understanding of equipment capabilities and characteristics and their influence on the workflow. Traditional approaches require new analysis with changing situations in the fab, which require special expertise and time. To enable a companywide standard and provide an easy to use tool, we are developing a utilization limit estimation tool. In this paper, we present our approach for a utilization target estimation system which bases its estimation on a wide range of data points created by data farming. Then, we apply a regression analysis to interpolate missing data points in order to provide fast estimates for utilization limits depending on equipment characteristics.

MILITARY, HOMELAND SECURITY AND EMERGENCY RESPONSE / CHARLESTON A

Networks, Refugees and Vortices

Julia Phillips (Argonne National Laboratory)

Network Layer Connectivity Awareness with Application to Investigate the OLSR Protocol in Tactical MANETs / Ming Li, Mazda Salmanian, and Tricia J. Willink (Defence Research and Development Canada)

We propose a new local networking metric, the network layer connectivity awareness (NLCA), to dynamically characterize the connectivity status at the network layer of mobile ad hoc networks (MANETs). The NLCA is a local view of routable destinations provided by a designated routing protocol, which may differ from the real-time physical layer connectivity (PHYCON), defined as destinations that can be reached by local nodes via (multi-hop) radio links. Such discrepancy can cause packet delivery failure because a route may no longer be available at physical layer. We present a simulation method to obtain the real-time PHYCON using the breadth-first search algorithm. We apply the NLCA metric to the optimized link state routing (OLSR) protocol in scenarios simulating tactical MANETs, and compare the resulting NLCA with the underlying PHYCON, illustrating the two measurements vary and differ under mobility. The proposed NLCA and investigation technique provide a method for routing performance analysis.

Balancing National Security and Refugee Rights Under Public International Law / Mariusz Adam Balaban (U.S. Army) and Paweł Mielniczek (University of Warsaw)

Does the national security exception in international refugee law constitute a real, legally measurable justification, or rather an excuse for introducing the politics according to the will of current government? A lack of sufficiently comprehensive set of rules within the 1951 Convention Relating to the Status of Refugees entails large, but not unlimited, subjectivity in interpreting legal norms. This work briefly presents the relevant legal norms and proposes a model aiming to balance between refugees' rights and national security interests. The model can help in limiting subjectivity during adjudication process by quantifying the boundaries to implementation of the limitations of refugees' rights. The provided example demonstrates the use of the model.

Simulation of the January 2014 Polar Vortex and Its Impacts on Interdependent Electric-Natural Gas Infrastructure / Edgar C. Portante, James A. Kavicky, Brian A. Craig, Leah Talaber, and Stephen M. Folga (Argonne National Laboratory)

The development of tools that appropriately simulate electric-natural gas interdependencies and their resulting propagation of disturbances within and between systems is a particular need of system operators. The need for such tools is further emphasized by the January 2014 Polar Vortex event, where the response of the electric power and natural gas systems further highlighted the importance of the coordinated assessment of interdependent systems when a large diversion of natural gas to non-electric customers created unexpected consequences in the electric sector. This paper documents ongoing modeling and assessment activities of the Argonne Electric Power-Natural Gas Integrated Model and demonstrates the estimated impacts for this historic disruptive event. This

paper presents a description of the Polar Vortex event, the modeling approach and methods used, including the assumptions, data, and modeling platform, and provides simulation results showing agreement with historically reported impacts, in both spatial and quantitative terms, to validate model performance.

SOCIAL AND BEHAVIORAL SIMULATION / VISTAS

Demographic Simulation

Carmen Iasiello (George Mason University)

Using Agent Based Modeling to Replicate Origins of Social Complexity: The Case of Limited Evidence in the Late Longshan Cultures and Early Erlitou Culture / Carmen Arleth Iasiello (George Mason University)

Within the archaeological record for Bronze Age Chinese culture, there continues to be a gap in our understanding of the sudden rise of the Erlitou State from the previous late Longshan chiefdoms. In order to examine this period, I develop and use an agent based model (ABM) to explore possible socio-politically relevant hypotheses for the gap between the demise of the late Longshan cultures and rise of the first state level society in East Asia. I test land use strategy making and collective action in response to drought and flooding scenarios, the two plausible environmental hazards at that time. The model results show cases of emergent behavior where an increase in social complexity could have been experienced if a catastrophic event occurred while the population was sufficiently prepared for a different catastrophe, suggesting a plausible lead for future research into determining the life of the time period.

Practical Application of Wedding Ring in Agent-based Demographic Simulation / Jeongsik Kim (Ulsan National Institute of Science and Technology); Euihyun Paik, Chun-Hee Lee, and Jang Won Bae (Electronics Telecommunications Research Institute); and Namhun Kim (Ulsan National Institute of Science and Technology)

The applicability of Wedding Ring model to an agent-based demographic module is investigated. As interpretation of social simulation results requires in-depth understanding of phenomena from various angles in the spatio-temporal dimension, the agent-based modeling (ABM) approach in demographic and social studies gets popular. To provide with quantitative information about chronological dynamics, computational cost and influential networks for the implemented model, we first introduce the Wedding Ring model which captures empirical marriage patterns based on a micro-level hypothesis and its outputs which are directly affected by social interactions. Then, the key observations are examined at different points in time, population size, and distribution of social networks to check its desirability for representational details of ABMs. In conclusion, the presented model could be extended into a large-scale social laboratory with acceptable predictability and computation load to allow for investigating non-numerical characteristics while supporting traditional approaches in a complementary rather than competitive way.

A Generative Stochastic Graphical Model for Simulating Social Protest / Dharmashankar Subramanian (IBM Research) and Lucia Titus (NC State University)

Civilian protest is a complex phenomenon where large numbers of protestors participate in demonstrations. It involves multiple groups, various trigger events and social reinforcement where groups excite each other. We present a graphical generative model in which a baseline spontaneous process may undergo excitation due to external triggers, as well as inter-group contagion. We define a trigger-conditional multivariate Hawkes process, where excitation is conditional on the presence of active triggers. An arrival in this process corresponds to a batch of protestors, and random marks on the arrival serve to capture both the excitation-related parameters as well as the size of protest. The batch arrival intensity and the batch size, while mutually independent, exhibit respective history-dependence due to memory that is modeled in the excitation phenomena. We present a simulation algorithm for generating sample paths, and results estimating likelihood of large-scale protest on a realistic model.

Tuesday 10:00a.m.-11:30a.m.

HISTORY OF SIMULATION / TRAILS

History of Simulation Inputs

Laurel Travis (VATECH)

History of Input Modeling / Russell Cheng (University of Southampton)

In stochastic simulation, input modeling refers to the process of identifying and selecting the probability distributions, called input models, from which are generated the random variates that are the source of the stochastic variation in the simulation model when it is run. This article reviews the history of the development and use of such models with the main focus on discrete-event simulation (DES).

History of Uniform Random Number Generation / Pierre L'Ecuyer (University of Montreal)

Random number generators were invented before there were symbols for writing numbers, and long before mechanical and electronic computers. All major civilizations through the ages found the urge to make random selections, for various reasons. Today, random number generators, particularly on computers, are an important (although often hidden) ingredient in human activity. In this article, we give a historical account on the design, implementation, and testing of uniform random number generators used for simulation.

History of Random Variate Generation / Michael Kuhl (Rochester Institute of Technology)

Random variate generation is a fundamental aspect of simulation modeling and analysis. The objective of random number generation is to produce observations that have the stochastic properties of a given random variable. To this end, methods and algorithms have been developed to generate random variates that are accurate (representative of the target distribution) and computationally efficient. This paper presents a history of random variate generation including distribution sampling methods used prior to the introduction of digital computers, as well as the evolution of random variate generators for continuous and discrete distributions and stochastic point processes.

INTRODUCTORY TUTORIALS / RED ROCK G

A Tutorial on Simulation Conceptual Modeling

Tillal Eldabi (Brunel University)

A Tutorial on Simulation Conceptual Modeling / Stewart Robinson (Loughborough University)

Conceptual modeling is the abstraction of a simulation model from the part of the real world it is representing; in other words, choosing what to model, and what not to model. This is the most difficult, least understood, but probably the most important activity in a simulation study. In this tutorial we explore the definition, requirements and approach to conceptual modeling. First we ask 'where is the model?' We go on to define the term 'conceptual model', to identify the artefacts of conceptual modeling, and to discuss the purpose and benefits of a conceptual model. In so doing we identify the role of conceptual modeling in the simulation project life-cycle. The discussion then focuses on the requirements of a conceptual model, the approaches for documenting a conceptual model, and frameworks for guiding the conceptual modeling activity. One specific framework is described and illustrated in more detail.

ADVANCED TUTORIALS / VERANDA C

Power Consumption in Parallel and Distributed Simulations

Dong Jin (Illinois Institute of Technology)

Power Consumption in Parallel and Distributed Simulations / Richard Fujimoto (Georgia Institute of Technology)

The energy and power consumed by computing applications have long been important concerns in mobile systems and have recently become of great interest in high performance and cloud computing. To date, only a limited amount of work has considered power consumption in parallel and distributed simulation

systems. A variety of options to reduce power consumption in these systems are discussed, suggestive of directions for future research in this increasingly important area.

MODELING METHODOLOGY / RED ROCK I

Computing Systems

Chris Myers (University of Utah)

An Analytical Memory Hierarchy Model for Performance Prediction / Gopinath Chennupati, Nandakishore Santhi, Stephan Eidenbenz, and Sunil Thulasidasan (Los Alamos National Laboratory)

As the US Department of Energy (DOE) invests in exascale computing, performance modeling of physics codes on CPUs remains a hard challenge in computational co-design, specifically, due to the complex design of processors. Herein, we introduce Analytical Memory Model (AMM), a novel hardware model based on cache memory hierarchies that predicts the runtimes of scientific applications while addressing the co-design challenges. AMM runtime prediction depends on the distribution of reuse distances, which are measured from the memory trace of the scientific applications. The analytical reuse distribution is useful to estimate the effective latency and throughput of a memory access, which in turn are used to predict the overall runtime of a scientific application. The experimental results show that the predicted and actual runtimes of two scientific mini-applications (matrix multiplication and Blackscholes) are similar, while AMM is a scalable approach.

Simulation of HPC Job Scheduling and Large-Scale Parallel Workloads / Mohammad Abu Obaida and Jason Liu (Florida International University)

The paper presents a simulator designed specifically for evaluating job scheduling algorithms on large-scale HPC systems. The simulator was developed based on the Performance Prediction Toolkit (PPT), which is a parallel discrete-event simulator written in Python for rapid assessment and performance prediction of large-scale scientific applications on supercomputers. The proposed job scheduler simulator incorporates PPT's application models, and when coupled with the sufficiently detailed architecture models, can represent more realistic job runtime behaviors. Consequently, the simulator can evaluate different job scheduling and task mapping algorithms on the specific target HPC platforms more accurately.

Using Quality of Service Lanes to Control the Impact of Raid Traffic Within a Burst Buffer / Elsa Gonsiorowski (Lawrence Livermore National Laboratory), Christopher D. Carothers (Rensselaer Polytechnic Institute), Justin LaPre (Rensselaer Polytechnic Institute), Philip Heidelberger (IBM T.J. Watson Research Center), and Cyriel Minkenberg and German Rodriguez (Rockley Photonics)

The next generation of leadership supercomputer systems will require a medium-term layer of storage. The basis for this stratum of storage will be a Storage I/O Node (SION). For increased reliability, a redundancy algorithm will be implemented on top of groups of SIONs. In addition to the overheads of implementing a redundancy mechanism, a large cost of using a RAID strategy comes from the possibility of increased network congestion due to rebuild operations. To better understand the impact of RAID rebuild traffic, we have developed a simulation model of the SIONs. After validation, we use this model to investigate the impact of several configuration parameters, including redundancy mechanism and the physical arrangement of hardware. Additionally, our model analyzes the use of Quality of Service lanes to limit the impact of RAID traffic. We conclude with a series of recommendations for configuring a resilient and high performing I/O subsystem.

AGENT-BASED SIMULATION / RED ROCK H

Global Security-Related Applications

Paul Goldsman (self-employed)

Surrogate Assisted Calibration Framework for Crowd Model Calibration / Wenchao Yi (Nanyang Technological University), Jinghui Zhong (South China University of Technology), Singkuang Tan and Wentong Cai (Nanyang Technological University), and Nan Hu (Agency for Science Technology and Research)

Surrogate models are commonly used to approximate the multivariate input or output behavior of complex systems. In this paper, surrogate assisted calibra-

tion frameworks are proposed to calibrate the crowd model. To integrate the surrogate models into the evolutionary calibration framework, both the offline and online training based approaches are developed. The offline training needs to generate training set in advance, while the online training can adaptively build and re-build the surrogate model along the evolutionary process. Our simulation results demonstrate that the surrogate assisted calibration framework with the online training is effective and the surrogate model using artificial neural network obtains the best overall performance in the scenario evaluated in the case study.

Simulating DDoS Attacks on the US Fiber-Optics Internet Infrastructure / Sumeet Kumar and Kathleen M. Carley (Carnegie Mellon University)

Network-based attacks like the distributed denial-of-service (DDoS) attacks are not new, but we are beginning to see attacks of unprecedented scale. Examples of such attacks include the 2016 attack on DYN INC that crippled a part of the Internet for hours, and the attack on Liberia, which partially brought down the African nation. Limitations in identifying vulnerable Internet infrastructure and testing possible defense strategies are a part of the problem. We need a simulation testbed that can reflect the complexity of the Internet, yet allows to swiftly test attacks, providing insights that can apply to real-world attack scenarios. In this research, we have designed a test-bed that mirrors the Internet infrastructure of the US and can simulate the Internet traffic flow patterns for different attack targets. We also estimate the degradation in the quality-of-service and the number of users impacted in two attack scenarios.

Towards an Automated Framework for Agent-based Simulation of Refugee Movements / Diana Suleimenova, David Bell, and Derek Groen (Brunel University London)

Forced migration is a growing global problem, and the world now has a record amount of 22.5 million refugees. Models that predict refugee movements are few and far between, and constructing these models requires a substantial amount of manual effort while erupting refugee crises require a very rapid response. Here we present a vision towards establishing an automated framework, aimed to enable researchers to construct simulations of refugee movements more quickly and systematically. Our approach incorporates a diverse range of data sources, and uses the FabSim toolkit in conjunction with the Flee simulation code to quickly generate simulation workflows. In addition, we highlight a few key steps that we have already taken towards realizing this vision and discuss opportunities for wider applicability.

HYBRID SIMULATION / HILLS

Hybrid Simulation in Healthcare

Sally Brailsford (University of Southampton)

Using Discrete Event Simulation and Soft Systems Methodology for Optimizing Patient Flow and Resource Utilization at the Surgical Unit of Radium-hospitalet in Oslo, Norway / Lene Berge Holm (Oslo and Akershus University College of applied sciences) and Tone Bjornenak, Guri Galtung Kjaeserud, and Harald Noddeland (Oslo University Hospital HF)

This study has a multimethodological approach where discrete event simulation (DES) modelling and Soft Systems Methodology (SSM) is used in combination at the surgical unit of The Norwegian Radium Hospital. The aim was to investigate the effect of different interventions on patient flow and resource utilization. The multimethodological approach ensured well anchoring and a feeling of ownership of the project among all staff groups. This increases the probability of acceptance of model results. The multimethodology also ensured that it was the most relevant, desirable and feasible interventions that was evaluated with the simulation model. This project has provided the hospital management with a massive amount of structured information, based both on results from the SSM and the DES processes. Several assumptions have been quantified and are used as tools in the discussion on how to meet the increased demand of cancer surgeries due to recently implemented cancer pathways in Norway.

Optimizing Home Hospital Service Delivery in Norway using a Combined Geographical Information System, Agent Based, Discrete Event Simulation Model. / Joe Viana and Vigdis M. Ziener (Oslo University Hospital), Irene G. Ponton (Akershus University Hospital), Marita S. Holhjem (Oslo University Hospital), and Lise J. Thøgersen and Tone B. Simonsen (Akershus University Hospital)

Home hospital services; provide some hospital level services at the patient's residence. The services include for example : palliative care, administering chemotherapy drugs, changing dressings and care for newborns. The rationale of the service is that by providing high quality care to patients at their homes their experience of the care is better and hence they respond to the treatment and/or recover quicker and are less likely to need to report to hospital to receive care for more serious/expensive conditions. The aim of this study is to evaluate the effectiveness of the home hospital service, to optimize the current configuration given existing constraints and to evaluate potential future scenarios. Using a combined discrete event simulation, agent based model and geographical information system we assess the system effects of different demand patterns, appointment scheduling algorithms (e.g. travelling salesman problem), varying levels of resource on patient outcomes and impact on hospital visits.

Combining Bootstrap-based Stroke Incidence Models with Discrete Event Modeling of Travel-Time and Stroke Treatment: Non-Normal Input and Non-Linear Output / Kim Rand-Hendriksen, Joe Viana, and Fredrik Dahl (Akershus University Hospital)

Incidence rates in simulation models are often assumed to stem from Poisson processes, with rates based on analyses of real-life data. In cases where the record of data is limited, or observed rates are low, the stochastic process involved in sampling from modeled distributions may not adequately reflect the uncertainty around the estimated input parameters. We present a conceptually simple, but computationally demanding, method for generating variance in incidence through the use of bootstrapping; for each subsample, a regression model is fitted, and the simulation model is run repeatedly sampling from the fitted model. Stochasticity is introduced at two levels; data for fitting the regression, and sampling from the fitted model. We illustrate this hybrid approach using Norwegian stroke records to generate stroke incidences with age, sex, and location, in a simulation model made to analyze travel time, queuing, and time to treatment in regional stroke units.

ANALYSIS METHODOLOGY / VERANDA B

Simulation Output and Uncertainty

Susan Hunter (Purdue University)

On the Estimation of the Mean Time to Failure by Simulation / Peter W. Glynn (Stanford University), Marvin K. Nakayama (New Jersey Institute of Technology), and Bruno Tuffin (INRIA)

The mean time to failure (MTTF) of a stochastic system is often estimated by simulation. One natural estimator, which we call the direct estimator, simply averages independent and identically distributed copies of simulated times to failure. When the system is regenerative, an alternative approach is based on a ratio representation of the MTTF. The purpose of this paper is to compare the two estimators. We first analyze them in the setting of crude simulation (i.e., no importance sampling), showing that they are actually asymptotically identical in a rare-event context. The two crude estimators are inefficient in different but closely related ways: the direct estimator requires a large computational time because times to failure often include many transitions, whereas the ratio estimator entails estimating a rare-event probability. We then discuss the two approaches when employing importance sampling; for highly reliable Markovian systems, we show that using a ratio estimator is advised.

Variance and Derivative Estimation for Virtual Performance in Simulation Analytics / Yujing Lin and Barry L. Nelson (Northwestern University)

Virtual performance is a class of time-dependent performance measures conditional on a particular event occurring at time t_0 for a (possibly) nonstationary stochastic process; virtual waiting time of a customer arriving to a queue at time t_0 is one example. Virtual statistics are estimators of the virtual performance. In this paper, we go beyond the mean to propose estimators for the variance, and for the derivative of the mean with respect to time, of virtual performance, examining both their small-sample and asymptotic properties. We also provide

a modified K-fold cross validation method for tuning the parameter k for the difference-based variance estimator, and evaluate the performance of both variance and derivative estimators via controlled studies. The variance and derivative provide useful information that is not apparent in the mean of virtual performance.

Analyzing and Simplifying Model Uncertainty in Fuzzy Cognitive Maps / Eric A. Lavin and Philippe Giabbanelli (Northern Illinois University)

Fuzzy Cognitive Mapping (FCM) represents the ‘mental model’ of individuals as a causal network equipped with an inference engine. As individuals may disagree or evidence be insufficient, causal links may be assigned a range rather than one value. When all links have range, the massive search space is a challenge to running simulations. In this paper, we presented, implemented, and evaluated a new approach to identify which ranges are important and simplify models accordingly. Our approach uses a factorial design of experiments, implemented using parallelism to offset its high computational cost. Our implementation (including our new Python library for FCM) is freely available on a third-party repository. Our evaluation on three previously published models shows that our approach can simplify almost half of a model under common settings, and runs within seconds on entry-level hardware for small FCMs. Further research is needed on simplifying the few FCMs having many links.

SIMULATION OPTIMIZATION / VERANDA D

Bayesian Ranking and Selection

Ilya Ryzhov (University of Maryland)

A Bayesian Ranking and Selection Problem with Pairwise Comparisons / Laura Priekule and Stephan Meisel (University of Münster)

We consider a ranking and selection problem where sampling of two alternatives at once is required for learning about the true performances of the individual alternatives. The true performance of an alternative is defined as its average probability of outperforming the other alternatives. We derive and numerically compare four different solution approaches. Two Knowledge Gradient sampling policies are compared with a pure exploration policy and with a knockout tournament. The knockout tournament serves as a natural benchmarking approach with respect to pairwise comparisons, and determines the sampling budget provided to the other approaches. Our numerical results show that the Knowledge Gradient policies outperform both knockout tournament and pure exploration, and that they lead to significant improvements already at a very small number of pairwise comparisons. In particular we find that a nonstationary Knowledge Gradient policy is the best of the considered approaches for ranking and selection with pairwise comparisons.

Efficient Expected Improvement Estimation for Continuous Multiple Ranking and Selection / Michael Arthur Leopold Pearce and Juergen Branke (University of Warwick)

This paper considers the problems of identifying the best of a discrete set of alternatives for each of a set of correlated problem instances that can be described by a set of continuous features, and where the performance of a particular alternative on a particular problem instance can only be estimated from noisy samples. A possible application is in manufacturing, where we would like to identify the best dispatching rule to be used depending on shop floor conditions, and performance is estimated via stochastic simulation. We propose three myopic sequential sampling methods to collect information, and in particular focus on an efficient estimation of the expected improvement which requires integration over the continuous space of problem instances. Empirical tests show that our method of estimating expected improvement is indeed more efficient than standard Monte Carlo integration, and that our method significantly outperforms a recently published alternative sampling method.

Rate-Optimality of the Complete Expected Improvement Criterion / Ye Chen and Ilya Ryzhov (University of Maryland)

Expected improvement (EI) is a leading algorithmic approach to simulation-based optimization. However, it was recently proved that, in the context of ranking and selection, some of the most well-known EI-type methods cause the probability of incorrect selection to converge at suboptimal rates. We investigate a more recent variant of EI (known as “complete EI”) that was proposed by Salemi, Nelson, and Staum (2014), and summarize results showing that, with

some minor modifications, complete EI can be made to achieve the optimal convergence rate in ranking and selection with independent Gaussian noise. This is the strongest theoretical guarantee available for any EI-type method.

SIMULATION OPTIMIZATION / PAVILION

Parallelization and Experimentation of Simulation Optimization Algorithms

Giulia Pedrielli (Arizona State University)

Optimal Design of Master-worker Architecture for Parallelized Simulation Optimization / Haobin Li (Institute of High Performance Computing, A*STAR Singapore); Giulia Pedrielli (Arizona State University); Loo Hay Lee (National University of Singapore); and Xiuju Fu and Xiao Feng Yin (Institute of High Performance Computing, A*STAR Singapore)

This study formulates and solves the design problem for a master-worker architecture dedicated to the implementation of a parallelized simulation optimization algorithm. Such a formulation does not assume any specific characteristic of the optimization problem being solved, but the way the algorithm is parallelized. In particular, we refer to the master-worker paradigm, where the master makes sampling decisions while the workers receive solutions to evaluate. We identify two metrics to be optimized: the throughput of the workers in terms of the number of evaluations per time unit, and the lack of synchronization between the master and the workers. We identify several design parameters: number of workers (n), the buffer size for each worker and for the master and the sample size m as the number of solutions used by the master for sampling decisions at each iteration. Numerical experiments show optimal designs over randomly generated simulation optimization algorithm instances.

Application of a Second-order Stochastic Optimization Algorithm for Fitting Stochastic Epidemiological Models / Atiye Alaeddini and Daniel Klein (Institute for Disease Modeling)

Epidemiological models have tremendous potential to forecast disease burden and quantify the impact of interventions. Detailed models are increasingly popular, however these models tend to be stochastic and very costly to evaluate. Fortunately, readily available high-performance cloud computing now means that these models can be evaluated many times in parallel. Here, we briefly describe PSPO, an extension to Spall's second-order stochastic optimization algorithm, Simultaneous Perturbation Stochastic Approximation (SPSA), that takes full advantage of parallel computing environments. The main focus of this work is on the use of PSPO to maximize the pseudo-likelihood of a stochastic epidemiological model to data from a 1861 measles outbreak in Hagelloch, Germany. Results indicate that PSPO far outperforms gradient ascent and SPSA on this challenging likelihood maximization problem.

Empirically Comparing the Finite-Time Performance of Simulation-Optimization Algorithms / Naijia Dong and David Eckman (Cornell University), Matthias Poloczek (University of Arizona), and Xueqi Zhao and Shane Henderson (Cornell University)

We empirically evaluate the finite-time performance of several simulation-optimization algorithms on a testbed of problems with the goal of motivating further development of algorithms with strong finite-time performance. We investigate if the observed performance of the algorithms can be explained by properties of the problems, e.g., the number of decision variables, the topology of the objective function, or the magnitude of the simulation error.

ARCHITECTURE AND CONSTRUCTION / VERANDA A

Smart Buildings / Data Integration

Amin Hammad (Concordia University)

Towards Systematic Reliability Modeling of Smart Buildings / Sanja Lazarova-Molnar, Elena Markoska, and Hamid Reza Shaker (University of Southern Denmark)

Building Management Systems (BMS) monitor and control smart buildings. We are witnessing a trend of BMS becoming increasingly sophisticated and delivering more advanced services. The downside of this is that the complexity of BMS is also increasing, thus, making smart buildings vulnerable to various malfunctions and faults. We anticipate that reliability of smart buildings will

be gaining in importance, especially for BMS of critical buildings, such as hospitals or buildings that host emergency services or store sensitive materials or technologies, whose unreliable operation could have catastrophic consequences. The assistance, however, is in the large amounts of easily available data that implies possibilities for development of highly accurate reliability models. Cloud computing can be also utilized to support collaborative sharing and benefitting from each other building's data. To utilize all of the above stated, we have developed a cloud-based BMS reliability analysis framework that we describe and illustrate in this paper.

Hybrid Metaheuristic Experiments of Real-time Adaptive Optimization of Parametric Shading Design through Remote Data Transfer / Hwang Yi (Florida International University)

The author seeks a practical approach to complement deterministic design optimization in performance-based building design. This study investigates algorithmic processes to test and monitor the dynamic optimal control of building components. To this end, an integration of wireless data transfer equipment (nRF24L01) and a customized metaheuristic hybrid optimization algorithm (Tabu-based adaptive pattern search simulated annealing, T-APSSA) through a parametric visual programming language (VPL) interface (Rhino grasshopper®) is presented with experimental design of a responsive kinetic shading device. To demonstrate the performance of the algorithmic hybridization and early design integration, T-APSSA is compared to simulated annealing and pattern (direct) search, and two different approaches to daylight-optimized design solutions are tested: a deterministic optimization based on historical weather data and a site-specific adaptive optimization according to real-time monitoring of incident solar radiance. The suggestion of a seamless environmental building design workflow through remote data communication contributes to strengthening intelligent architectural design decisions.

Synthesizing Engineering Design, Material Takeoff and Simulation-Based Estimating on a Bridge Deck Reinforcement Case / Ming Lu, Chaoyu Zheng, Chaojue Yi, and Monjurul Hasan (University of Alberta)

To enhance the accuracy in estimating material and crew costs for steel reinforcement installation, numerous estimating tools have been developed. "Precise estimating" in general considers both lapping details and other required supporting structures while deriving the crew cost by accounting for reinforcing operations. In contrast, "rough estimating" ignores rebar lapping details in quantity takeoff and relies on industry benchmark productivity data for crew cost estimation. The distinction between "precise estimating" and "rough estimating" still lacks quantitative evidence and remains vague to both academic researchers and professional estimators. This research presents systematic comparison between the two estimating strategies with a case study of a bridge deck. A discrete event simulation tool is used to aid in estimating the crew cost in reinforcement handling and installation. The estimating results indicate that compared with the "precise estimating" approach, the "rough estimating" approach underestimates the material and crew costs by 13% and 38%, respectively.

HEALTHCARE APPLICATIONS / CHARLESTON C

Patient Flow Through Health Care Processes

Ki-Hwan G. Bae (University of Louisville)

Simulating Triage of Patients into an Internal Medicine Department to Validate the Use of an Optimization-based Workload Score / Joseph Agor, Kendall McKenzie, Maria Mayorga, and Osman Ozaltin (North Carolina State University) and Riddhi Parikh and Jeanne Huddleston (Mayo Clinic)

This study describes a simulation model that was used to evaluate a proposed workload score. The score was designed to assist in triaging patients into the hospital services of the Division of Hospital Internal Medicine at Mayo Clinic in an effort to more equitably balance workload among the division's provider teams (or services). The first part of this study was the development of a score, using Delphi surveys, conjoint analysis, and optimization methods, that accurately represents provider workload. A simulation model was then built to test the score using historical patient data. Preliminary simulation results reported the proportion of time that each provider team spent working at or above "maximum utilization," as defined by Mayo Clinic experts. The model yielded a 12.1% decrease (on average) in the proportion of time provider teams spent at or above maximum utilization, while simultaneously displaying a more balanced workload across provider teams.

Proactive Patient Flow Redesign for Integration of Multiple Outpatient Clinics / Vahab Vahdat, Jacqueline Griffin, Sarah Burns, and Rana Azghandi (Northeastern University)

Successful merging or consolidation of interdependent healthcare clinics have been shown to have benefits with regards to decreasing operation costs while maintaining patients' quality of care. In order to achieve a successful merger or integration of clinics, an analysis of the effects of integrating patient flows should occur. This is especially important when the merger of clinics involves a transition into a new facility. We utilize a discrete event simulation model to study the effects of integrating three interdependent musculoskeletal clinics, Orthopedics, Rheumatology, and Radiology, into a new facility in advance of implementation. Through use of the simulation, unexpected bottlenecks in the check-in process are identified and the effects of implementing new patient flows, supported by Real-Time Location System (RTLS) technology, are analyzed.

Performance Evaluation of Respite Care Services Through Multi-Agent Based Simulation / Oussama Batata, Vincent Augusto, Setareh Ebrahimi, and Xiaolan Xie (Mines Saint-Etienne)

Caregivers of patients with chronic diseases are undergoing a daily burnout in their lives. Although respite care seems a promising solution, no quantitative analysis has yet been provided to demonstrate its positive impact. In this article, we propose (i) a new model of caregivers' burnout evolution based on Markov chain and machine learning to model health state evolution, and (ii) a multi-agent based simulation approach to describe the burnout evolution of caregivers and impact of respite structures on the system. Optimal capacity of respite structures is obtained through a design of experiment. Several management strategies are also tested (collaboration between structures, reservation of beds for emergent cases). Key performance indicators considered are quality of service and costs. Results show a positive impact of respite services on both quality of service and costs. The model also show a trade-off between quality of service and costs when bed reservation policies are used.

LOGISTICS, SCM, TRANSPORTATION / CHARLESTON E

Simheuristics for Logistics, SCM and Transportation (2)

Reha Uzsoy (North Carolina State University)

Flow-Time Estimation by Synergistically Modeling Real and Simulation Data / Hoda Sabeti and Feng Yang (West Virginia University)

The ability to quote a competitive and reliable lead time for a new order is a key competitive advantage for manufacturers and plays a significant role in customer acquisition and satisfaction. Quoting a precise and reliable lead time requires a good prediction for the flow time of a new order. This research focuses on quantifying the dependence of the flow time upon observed job shop status variables, the size of a new order, and arrival rate of future orders. An iterative fitting procedure based on stochastic kriging with qualitative factors model (SKQ), is developed to synergistically model simulation and real manufacturing data, for the prediction of a new order's flow time.

A Heteroscedastic t-Process Simulation Metamodeling Approach and Its Application in Inventory Control and Optimization / Guangrui Xie and Xi Chen (Virginia Tech)

In this paper we develop a heteroscedastic t-process metamodeling approach (TP) for approximating the mean response surface implied by a stochastic simulation and performing metamodel-based optimization. We provide details on how to construct a TP metamodel, make inference and perform prediction based on TP. We show that TP can retain the attractive properties of approaches that rely on Gaussian process, but it also enjoys enhanced flexibility, at no additional computational cost. We further provide a close-form expression for the TP-based expected improvement to perform metamodel-based optimization. We compare the predictive performance of TP and stochastic kriging (SK) via an M/M/1 inspired example, and demonstrate the performance of TP and SK-based algorithms for optimizing a simple periodic review (s,S) inventory system.

An Iterative Refinement Approach to Fitting Clearing Functions to Data from Simulation Models of Production Systems / Karthick Gopalswamy and Reha Uzsoy (North Carolina State University)

We examine the problem of fitting clearing functions that estimate the expected

output of a production resource as a function of its expected workload from empirical data. Unlike most regression problems, the independent variables are not directly controllable due to the presence of a planning model that controls releases to the production system, and the release decisions made by the planning model are themselves dependent on the estimated clearing function. We propose an iterative refinement procedure that uses simulation experiments to resample data from the production system as the parameters of the clearing function are iteratively updated. We compare the iterative procedure to previously used approaches with promising results.

LOGISTICS, SCM, TRANSPORTATION / SIENA

Uncertainty modeling in operations planning

Canan Gunes Corlu (Boston University)

Uncertainty Quantification on Simulation Analysis Driven by Random Forests / Amirhossein Meisami (University of Michigan), Henry Lam (Columbia University), and Mark P. Van Oyen (University of Michigan)

We consider simulation-based estimation where the inputs are calibrated from predictive models generated by random forests (RFs). RF is a common technique to produce ensemble predictions by aggregating many individual decision trees. This problem arises in data-driven applications such as individualized surgery operations scheduling and supply chain management. We investigate the estimation of the output variance contributed from the noises in the input prediction, which can be used to construct output confidence intervals. In particular, we study the integration of simulation runs with a recently proposed infinitesimal jackknife estimator that can reduce the computational burden from double layers of bootstrapping. We demonstrate our scheme with an elementary numerical example.

Simulation-Based Production Planning for Engineer-to-Order Systems with Random Yield / Alp Akcay and Tugce Martagan (Eindhoven University of Technology)

We consider an engineer-to-order production system with unknown yield. We model the yield as a random variable which represents the percentage output obtained from one unit of production quantity. We develop a beta-regression model in which the mean value of the yield depends on the unique attributes of the engineer-to-order product. Assuming that the beta-regression parameters are unknown by the decision maker, we investigate the problem of identifying the optimal production quantity. Adopting a Bayesian approach for modeling the uncertainty in the beta-regression parameters, we use simulation to approximate the posterior distributions of these parameters. We further quantify the increase in the expected cost due to the so-called input uncertainty as a function of the size of the historical data set, the product attributes, and economic parameters. We also introduce a sampling-based algorithm that reduces the average increase in the expected cost due to input uncertainty.

The Role of Learning on Industrial Simulation Design and Analysis / Bahar Biller, Stephan R. Biller, and Onur Dulgeroglu (GE Global Research) and Canan Gunes Corlu (Boston University)

The capability of imitating real-world system operations has turned simulation into an indispensable problem-solving methodology for business system design and analysis. Often, simulation supports decisions ranging from sourcing to operations to finance, starting at the strategic level and proceeding towards tactical and operational decision-making. In such a dynamic setting, the practice of simulation goes beyond being a static problem-solving exercise and requires integration with learning. This article discusses the role of learning on simulation design and analysis motivated by the needs of industrial problems. Examples are presented to describe how selected tools of machine learning can be utilized to drive learning in the design and analysis of simulations.

MASM / VERANDA E**Various Modeling Approaches in Semiconductor Manufacturing**

Hans Ehm (Infineon Technologies AG)

Classifying Defects in Topography Images of Silicon Wafers / Corinna Kofler and Gunter Spöck (Alpen-Adria-Universität Klagenfurt) and Robert Muhr (Infineon Technologies Austria AG)

In this work, we demonstrate that automatically classifying defects in topography images of silicon wafers is feasible. We process topography images of a set of sample wafers with controlled induced defects in their wafer back surfaces. We group these induced defects into three classes: cavities, cracks, and star cracks. With this sample set, we train and test selected classifiers with suitable feature vectors extracted from their wafer back surface topography images. A comparison reveals, that training and testing linear and quadratic classifiers with two Fisher scores as features, yield the best classification performances. We correctly classify all cavities and can separate them from the critical cracks and star cracks, which show a sufficient signal in the topography images.

Bridging Short and Mid-Term Demand Forecasting in the Semiconductor Industry / Nicola Sabrina Schuster (Technical University of Munich), Hans Ehm (Infineon Technologies AG), Andreas Hottenrott (Technical University of Munich), and Tim Lauer (Infineon Technologies AG)

Demand planning in the semiconductor industry is typically divided into different planning horizons, mid-term and short-term. Accurate demand forecasting is crucial because of long capacity installation times, long lead-times, short product life cycles, and constantly new technological advances. As demand forecasting for short and mid-term horizons are often made on different product and time granularities using different planning tools, we may see demand fluctuations (on the same granularity) within individual horizons and at the intersections of different granularities. This paper discusses stability of demand forecasts depending on time and product granularity and introduces definitions of good and bad stability, using Symmetric Mean Absolute Percentage Error (SMAPE) as a measure for stability. We show that time and product granularities have a significant effect on the intra-horizon stability of a demand plan and that planning on different granularities can lead to artificial demand fluctuations at the intersections of planning horizons.

Harmonizing Operations Management of Key Stakeholders in Wafer Fab Using Discrete Event Simulation / Georg Seidel (Infineon Technologies Austria AG), Ching Foong Lee and Ai Mei Kam (Infineon Technologies (Kulim) Sdn Bhd), Boon Ping Gan and Chew Wye Chan (D-SIMLAB Technologies Pte Ltd), and Andre Naumann and Patrick Preuss (D-SIMLAB Technologies GmbH)

Operations meeting in a wafer fab involves daily alignment of action items among key stakeholders: operations, maintenance, engineering and planning department. They have conflicting job functions. The maintenance department is required to conduct preventive maintenance (PM) to improve tools' reliability. The engineering department is required to qualify new products and processes. Both cases interfere with the flow of production lots. The planning department must ensure production ramp up. This can have a short term impact on overall fab delivery and capacity. The primary challenge is to reach aligned decisions: e.g. the best timing for PM or optimizing dispatch prioritization of production and development lots to ensure on-time delivery while maximizing capacity and tool utilization. In this paper we discuss the associated modelling issues of a 7-day simulation-based forecast, providing forecast of incoming WIP, moves and utilization at work center level. The simulation forecast consistently achieved an accuracy above 90%.

MANUFACTURING APPLICATIONS / CHARLESTON B**Simulation Based Scheduling**

Leon McGinnis (Georgia Institute of Technology)

Real-Time Job Shop Scheduling Based on Simulation and Markov Decision Processes / Tao Zhang, Shufang Xie, and Oliver Rose (Universität der Bundeswehr München)

Real-time job shop scheduling is a sequential decision making problem. The main task is to decide which job in a queue should be processed. The problem can be modeled as a Markov decision process. Jobs in the queue form an action

set. Selecting one job to process is regarded as taking an action from the set. A dummy action, which means no job will be selected and the machine will keep idle, is also contained in the action set. This removes the no-delay restriction from the problem. The reward function comprises the critical ratio of the selected job and the global job holding cost. Two algorithms, simulation-based value iteration and simulation-based Q-learning, are introduced to solve the scheduling problem from the perspective of a Markov decision process. The simulation explores the state space and accomplishes state transitions. The value function is parameterized and estimated by using a feedforward neural network.

Simulation-based Dynamic Shop Floor Scheduling for a Flexible Manufacturing System in the Industry 4.0 Environment / Wenhe Yang and Soemon Takakuwa (Chuo University)

The Industry 4.0 environment enables direct communication between the manufacturer's shop floor and a customer. Thus, the manufacturer is able to respond to the customers' requests more quickly, meaning that manufacturers must now more tightly control the shop floor planning and scheduling. Here we present a simulation-based scheduling model for Flexible Manufacturing System dynamic shop-floor control. The customer's order and the processing sequence table of the products are imported into the simulation model. Experiments are implemented for the case wherein the system encounters unexpected conditions. The proposed approach represents a potential tool for manufacturers to make decisions in the real time by further connecting to the Enterprise Resource Planning and Manufacturing Execution System.

Optimizing Production Allocation with Simulation in the Fashion Industry: A Multi-Company Case Study / Virginia Fani, Romeo Bandinelli, and Rinaldo Rinaldi (University of Florence)

Production Planning and Control (PP&C) has been deeply analyzed in the literature, both in general terms and focusing on specific industries, such as the fashion one. The paper aims to add a contribution in this field presenting an optimization model for the Fashion Supply Chain (FSC), developed considering an interdependent environment composed by a group of focal companies that work with both exclusive and not-exclusive suppliers. The proposed framework will combine simulation and optimization models based on parameters, decision variables, constraints and Objective Functions (OFs) collected through a literature review. The framework has been developed in a parametrical way, in order to fit the peculiarities of the different actors operating along the FSC. The empirical implementation of the framework has been conducted using data coming from fashion companies belonged to the same network, considering rush orders as stochastic events for the scenario analysis and Key Performance Indicators (KPIs) assessment.

MILITARY, HOMELAND SECURITY AND EMERGENCY RESPONSE / CHARLESTON A

Frameworks and Space

Raymond Hill (Air Force Institute of Technology)

Joint Military Space Operations Simulation as a Service / Erdal Cayirci (University of Stavanger) and Hakan Karapinar and Lutfu Ozcakir (HAVELSAN)

Our Training and Experimentation Cloud Architecture, namely the hTEC, is applied to joint military space operations simulation. The hTEC follows the recommendations on the modelling and simulation as a service (MSaaS) by NATO Science and Technology Organization. The space mission areas and their characteristics are investigated and the requirements are analyzed. The hTEC services are designed such that these requirements are fulfilled. Each service addresses the minimum set of functions that may be needed by a military space operations mission area, and can be run independently, federated as a composed service or linked into a software application. The designed joint military space operations simulation architecture is implemented in a testbed called the extended BSigma.

Conceptual Framework for an Automated Battle Planning System in Combat Simulations / Byron Harder (USMC) and Curtis Blais and Imre Balogh (Naval Postgraduate School)

Automated planning is a key to unlocking the next generation of human behavior modeling for military simulations. Automated planning is distinguished from other dynamic behavior by its ability to reason with predictions or assumptions

about future outcomes, which has traditionally been left to the meticulous effort of human modelers. In this paper, we present a conceptual planning framework as an architectural roadmap for the development of this kind of capability in support of modeling and simulation. This paper also presents an initial implementation of the framework in a representative combat simulation for exploring potential future opportunities for community advancement of the planning techniques.

The Role of Simulation Frameworks in Relation to Experiments / David King (AFIT), Douglas Hodson (AFIT/ENG), and Gilbert Peterson (AFIT)

The usefulness of software frameworks to support the development of military combat simulations is gaining attention. Using a framework increases model reuse and can avoid the duplication of infrastructure code used to support model and simulation application development. Simulation frameworks encourage defining abstractions for the domain of interest, which allow for multiple concrete (i.e., specific) implementations of models at varying levels of fidelity, resolution and/or detail to be produced and assembled. This flexibility leads to customized simulation applications that are focused and aligned to an envisioned conceptual model of a system of interest. However, the difference between a framework and a specific simulation application, and its relationship to experimentation is not always clear. This paper elaborates on these distinctions and addresses how software frameworks support experimental objectives.

SIMULATION EDUCATION / VISTAS

Educating Simulationists

Saikou Diallo (Virginia Modeling, Analysis and Simulation Center)

An R Package for Simulation Education / Barry Lawson (University of Richmond) and Lawrence M. Leemis (College of William & Mary)

R is free software for statistical computing, providing a variety of statistical and graphical functionality. For use in simulation education, R's capabilities help to develop student intuition. In this paper, we introduce the "simEd" package for R, written with a pedagogical focus. The package includes functions for generating discrete and continuous variates via inversion, with capabilities for independent streams and antithetic variates; for visualizing inversion in variate generation and the relationship to the pdf/pmf, cdf, and ecdf; for computing time-persistent statistics; for extensible single- and multiple-server queueing simulation; and includes data sets for input modeling and analysis. As we demonstrate using several illustrations, this package, along with native R functionality, provides a compelling case for using R in an introductory simulation course.

Automated Model Verification Using an Equivalence Test on a Reference Model / Akin Akbulut and Stephan Abke (University of Paderborn) and Christoph Laroque (University of Applied Sciences Zwickau)

In this article, a cross-tooling method for automated model verification is presented using a reference model. Furthermore, the method is implemented in teaching, using a web platform. The method bases on Yücesan and Schruben (1992), demonstrating a procedure for the examination of a structural and behavioral equivalence of two simulation models based on Simulation Graph models. However, Simulation Graph models are subject to an event-oriented modeling world view. Since current simulation tools use a process-oriented – easier to understand – modeling world view, a simple queuing model shows how transformation from a process-oriented world view (Simio, AnyLogic) takes place in an event-oriented world view (Simulation Graph models). A further step then checks the structural equivalence via an isomorphic mapping on the resulting planar graphs.

Approaches for Simulation Model Simplification / Durk-Jouke van der Zee (Faculty of Economics & Business, University of Groningen)

Simplification is considered a fundamental part of modelling and simulation. Model simplification is instrumental in creating models that are useful – by focusing on system elements that matter, and feasible – by reducing study efforts. Despite its widely acknowledged relevance simulation model simplification may still be considered an underdeveloped field. This is mirrored in existing literature, and course books. While the former shows a fragmented landscape in addressing the issue, the latter often offer little guidance for the (future) analyst. To foster further development of the field we assess current progress by providing a literature review. Issues addressed by the review concern: (i) definition and scope of model simplification, (ii) reasons for model simplification, (iii) drivers

of inappropriate model complexity, and (iv) approaches for model simplification. The review is meant to provide a useful overview of the work undertaken in this field, aiming to benefit educators, practitioners and researchers.

CASE STUDIES / CHARLESTON F

Manufacturing 1

Guodong Shao (National Institute of Standards and Technology)

Application of Core Technologies for Smart Manufacturing: a Case Study of Cost Benefit Analysis Based on Modeling and Simulation for Sustainability / Chanmo Jun, Ju Yeon Lee, and Bo Hyun Kim (Korea Institute of Industrial Technology) and Sang Do Noh (Sungkyunkwan University)

Recently, corporations around the world have been making numerous efforts to innovate manufacturing due to intensified competition. These innovations in manufacturing can be characterized as “smart” manufacturing technology, and include Cyber Physical System(CPS), Internet of Things(IoT), big data, and cloud computing as applications of diverse information technologies. This study introduces research that has focused on Material Flow Cost Accounting(MFCA) in consideration of sustainability, targeting vehicle recycling factories, using an Modeling and Simulation(M&S) technique, which is one of the core elements of actualizing CPS among the core technologies in smart factory manufacturing. Specifically, this study describes the process from entering necessary data for a simulation to model creation to MFCA analysis, and verifies the applicability of the system using test examples.

Knowledge Discovery in Simulation Data - A Case Study for a Backhoe Assembly Line / Niclas Feldkamp, Soeren Bergmann, and Steffen Strassburger (Ilmenau University of Technology); Thomas Schulze (Otto-von-Guericke-University Magdeburg); Praneeth Akondi (John Deere Technology Center); and Marco Lemessi (John Deere GmbH & Co. KG)

Discrete event simulation is an established and popular technology for investigating the dynamic behavior of complex manufacturing and logistics systems. Besides conventional simulation studies that focus on single model aspects answering project specific analysis questions, new methods of broad scale experiment design and system analysis emerge alongside new developments of computational power and data processing. This enables to investigate the bandwidth of possible system behavior in a more in-depth way. In this work we applied our previously developed methodology on knowledge discovery in simulation data onto an industrial case study for a backhoe loader manufacturing facility.

Flexible Processing Mix Strategy for Complexity of Automated Manufacturing System / Hayder Zghair (Kettering University) and Ahad Ali (Lawrence Tech University)

Deciding how to change/expand production processes of an automated system is a critical take for a manufacturer. The research focuses on gathering real-world industrial data for the existing stream of automated manufacturing processes to build an analytical modeling simulating an improvement methodology using computer software. The approach is a decision-lead tool for whether it is best to increase the capacity of the current dual-product line resources or build a second system having a dedicated production line for the complete variety. Rockwell Software (ARENA 14.7-Platform) has been used to test the alternatives along with a set of experimentations using the full factorial design. Results show that (1) to achieve 50% increase in the throughput of AMS, the two-line system far exceeds the need, and (2) determining the optimal cost of the current line processes is possible by increasing only the system resources capacity

CASE STUDIES / CHARLESTON D

Military

Jie Xu (George Mason University)

A Role for General Purpose Simulation in Campaign-level Operational Modeling / Michael Lehocky (Operations Research and Cost Analysis Solutions, LLC)

Military operational and other system-of-systems analysis efforts are usually facilitated by using highly complex and expensive capability-focused simulation models. For studies in which the principal elements of analysis focus on readiness, responsiveness or operational presence rather than kinetic effects and

entity interactions, models derived from general purpose simulation applications may provide a better balance of cost and stochastic fidelity than detailed high-resolution simulations or spreadsheet-based analytics. This case study explores USCG cutter operational presence modeling evolving from large-scale campaign simulation and point-solution models to a general purpose simulation implementation.

Using a Genetic Programming approach to Mission Planning to deliver more agile Campaign Level Modelling for Military Operational Research /

Paul Glover and Simon Collander-Brown (Defence Science and Technology Laboratory) and Simon J. E. Taylor (Brunel University London)

Defence in both the UK and the US is committed to innovate in order to stay ahead. This implies the need for supporting analytical tools at least as adaptive in their focus as the potential change to the military system of systems that such innovation may suggest. Current approaches to modelling and simulation (M&S) produce monolithic, user scripted, models that are not well suited to rapidly assessing innovative ways of operating. In the UK a simulation toolset has been developed to provide the necessary adaptability, enabling new simulations to be rapidly produced. This toolset contains a modular mission planner to automate generation of courses of action in what are potentially very different ways of doing business.

Calculation of Radiation Exchange Using Macro-Class View Factors /

Thomas P. Etheredge, Matthew C. Rigney, and Matthew B. Haynes (US Army / AMRDEC) and Brad H. Seal and Jamie E. Burns (Torch Technologies)

Radiation exchange for large-scale terrains measuring more than 100km² at resolutions of 0.25m and containing billions of facets is a very complex problem for thermal solver simulations. Traditional thermal solvers have used a ray-traced approach to solve the radiation exchange energies but lack fidelity and introduce sampling error due to the limited number of rays that can be cast due to exceedingly long runtimes. A new approach using macro-class view factor maps and statistical temperature distributions for the terrains allow for more accurate calculation of radiation exchange energies in a fraction of the time as the traditional ray-traced solutions.

Tuesday 12:20p.m.-1:20p.m.

TITAN KEYNOTE / SUMMERLIN BALLROOM

Titan Talk - Robert Sargent

Gabriel Wainer (Carleton University)

A Perspective on Fifty-five Years of the Evolution of Scientific Respect for Simulation / Robert G. Sargent (Syracuse University)

This paper gives a personal perspective on the evolution of discrete-event simulation—concentrating on how it moved from having an image from the 1950s through the 1980s of being a “brute force programming effort” and as a problem-solving “method of last resort” to today’s status where simulation enjoys “considerable scientific respect.” These days, simulation is often the solution “method of choice” and has gained much “scholarly respect.” This evolution changed simulation’s reliance on the use of “ad hoc methods” of solution on “early digital computers” to using simulation software systems containing “science-based methods” of solution on “modern day computers.” Remember: Simulation today has considerable scientific respect, and this respect is the result of the evolution of simulation.

ROBERT G. SARGENT is a Professor Emeritus at Syracuse University. He has made numerous contributions to the simulation community in the forms of both service work and scholarly publications. His many honors and awards include being a recipient of the 1988 Distinguished Service Award and the 2002 Lifetime Professional Achievement Award from I-SIM, the 2010 Board of Directors James R Wilson Award and the 40th Anniversary Landmark Paper Award from WSC, and the 2012 Distinguished Contributions Award from ACM/SIGSIM. Moreover, he was elected a Fellow of INFORMS in 2005. His email address is rsargent@syr.edu.

Tuesday 1:30p.m.-3:00p.m.

HISTORY OF SIMULATION / TRAILS

History of Simulation Computing

Abdullah Alabdulkarim (Majmaah University)

History of Computer Simulation Software: An Initial Perspective / Richard E. Nance (Virginia Tech (Retired)) and C. Michael Overstreet (Old Dominion University (Retired))

The evolution of computer simulation software until the mid-1980's is subsumed by descriptions of the history of simulation programming languages. Since that time, the entire complexion of simulation model design, development, execution, and sustainment has undergone a radical transition. The transition to a large degree stems from technology advances in hardware and software coupled with the increasing expectations of simulation modelers and end users. This study, covering the evolution in its entirety, represents an initial perspective on the transition based on an examination and analysis of the Winter Simulation Conference Archive and a partial set of simulation software surveys published in OR/MS Today. The results characterize the modeling and simulation software evolution since the mid-1980's in terms of newcomers, endurers, fads, fades, trends, and trajectories. Prominent among the conclusions are that commercial firms are driving the major advances and the marketplace is quite volatile.

Parallel Discrete Event Simulation: The Making of a Field / Richard Fujimoto (Georgia Institute of Technology); Rajive Bagrodia (Scalable Network Technologies Inc., University of California at Los Angeles); Randal Bryant (Carnegie Mellon University); K. Mani Chandy (California Institute of Technology); David Jefferson (Lawrence Livermore National Laboratory); Jayadev Misra (The University of Texas at Austin); David Nicol (University of Illinois, Urbana Champaign); and Brian Unger (University of Calgary, River Run Collaboratory Ltd.)

Originating in the 1970's, the parallel discrete event simulation (PDES) field grew from a group of researchers focused on determining how to execute a discrete event simulation program on a parallel computer while still obtaining the same results as a sequential execution. Over the decades that followed the field expanded, grew, and flourishes to this day. This paper describes the origins and development of the field in the words of many who were deeply involved. Unlike other published work focusing on technical issues, the emphasis here is on historical aspects that are not recorded elsewhere, providing a unique characterization of how the field was created and developed.

FUTURE OF SIMULATION / VERANDA A

Future of Simulation: Network and System Applications

Dong Jin (Illinois Institute of Technology)

Integrating Mathematical Optimization in DEVS for Nuclear Medicine Patient and Resource Scheduling / Eduardo Pérez (Texas State University)

Nuclear medicine is a subspecialty of radiology that uses advanced technology and radiopharmaceuticals for the diagnosis and treatment of medical conditions. Procedures in nuclear medicine require the use of radiopharmaceuticals, are multi-step, and have to be performed under strict time windows constraints. These characteristics make the scheduling of patients and resources in nuclear medicine challenging. In this work, we integrate DEVS and CPLEX, a mathematical programming optimization software, to develop a simulation-optimization scheduling methodology for nuclear medicine clinics. We report on computational results of the new model based on a real clinic, historical data, and both patient and management performance measures. The results show that new methodology provides on average an increase of 3% on patient throughput and a decrease of 20% on patient waiting time over a scheduling policy that was used in the clinic in the past.

A Hardware-in-the-loop Emulation Testbed for High Fidelity and Reproducible Network Experiments / Xiaoliang Wu, Qi Yang, Xin Liu, and Dong Jin (Illinois Institute of Technology) and Cheolwon Lee (National Security Research Institute of Korea)

The transformation of innovative research ideas to production systems is highly dependent on the capability of performing realistic and reproducible network experiments. In this work, we present a network testbed consisting of container-

based network emulation and physical devices to advocate high fidelity and reproducible networking experiments. The testbed integrates network emulators (Mininet), a distributed control environment (ONOS), and physical switches (Pica8). The testbed (1) offers functional fidelity through unmodified code execution in emulated networks, (2) supports large-scale network experiments using lightweight OS-level virtualization techniques and capable of running across distributed physical machines, (3) provides the topology flexibility, and (4) enhances the repeatability and reproducibility of network experiments. We validate the testbed fidelity through extensive experiments under different network conditions (e.g., varying topology and traffic pattern). We also use the testbed to reproduce key results from published network experiments, such as Hedera, a scalable and adaptive network traffic flow scheduling system.

A Brief History of HPC Simulation and Future Challenges / Kishwar Ahmed and Jason Liu (Florida International University), Abdel-Hameed Badawy (New Mexico State University), and Stephan Eidenbenz (Los Alamos National Laboratory)

High-performance Computing (HPC) systems have gone through many changes during the past two decades in their architectural design to satisfy the increasingly large-scale scientific computing demand. Accurate, fast, and scalable performance models and simulation tools are essential for evaluating alternative architecture design decisions for the massive-scale computing systems. This paper recounts some of the influential work in modeling and simulation for HPC systems and applications, identifies some of the major challenges, and outlines future research directions which we believe are critical to the HPC modeling and simulation community.

INTRODUCTORY TUTORIALS / RED ROCK G

Best Practices for Simulation Projects

Gerd Wagner (Brandenburg University of Technology)

Revisiting the Four C's of Managing a Successful Simulation Project / Melanie Barker and Nancy Zupick (Rockwell Automation)

This paper aims to discuss four key elements imperative to conducting an effective simulation study and how they impact the progress of the study. • The Clue: determining when and why to use simulation and what issues will be addressed • The Cash: understanding the financial costs and the impact of the project • The Commitment and the Courage: the importance of having a team committed to the endeavor and having the courage to make hard decisions so that the project will be successful Each of these key factors are critical to starting a successful project and keeping it on track towards proposing effective solutions for the problems the model was designed to address.

Avoid Failures! Tested Success Tips for Simulation Excellence / David T. Sturrock (Simio LLC)

How can you make your first project, and every project, successful? Modeling can certainly be fun, but it can also be quite challenging. You want your first and every project to be successful so you can justify continued work. Unfortunately a simulation project is much more than simply building a model — the skills required for success go well beyond knowing a particular simulation tool. A 30 year veteran who has done hundreds of successful projects shares important insights to enable project success. He also shares some cautions and tips to help avoid common traps leading to failure and frustration.

ADVANCED TUTORIALS / VERANDA C

Inside Discrete-Event Simulation Software: How It Works and Why It Matters

Hessam Sarjoughian (Arizona State University)

Inside Discrete-Event Simulation Software: How It Works and Why It Matters / Thomas J. Schriber (University of Michigan), Daniel T. Brunner (Dan Brunner Associates LLC), and Jeffrey S. Smith (Auburn University)

This paper provides simulation practitioners and consumers with a grounding in how discrete-event simulation software works. Topics include discrete-event systems; entities, resources, control elements and operations; simulation runs; entity states; entity lists; and their management. The implementations of these generic ideas in AutoMod, SLX, ExtendSim, and Simio are described. The

paper concludes with several examples of “why it matters” for modelers to know how their simulation software works, including discussion of AutoMod, SLX, ExtendSim, Simio, Arena, ProModel, and GPSS/H.

MODELING METHODOLOGY / RED ROCK I

Simulation Tools and Applications

Kalyan Perumalla (Oak Ridge National Laboratory)

The Modelverse: a Tool for Multi-Paradigm Modelling and Simulation / Yentl Van Tendeloo (University of Antwerp) and Hans Vangheluwe (University of Antwerp; Flanders Make vzw; McGill University)

Multi-Paradigm Modelling (MPM) has been proposed to tackle the complexities found in Cyber-Physical Systems. MPM advocates the explicit modelling of all pertinent parts and aspects of complex systems. It addresses and integrates three orthogonal dimensions: multi-abstraction modelling, concerned with the (refinement, generalization, ...) relationships between models; multi-formalism modelling, concerned with the (multi-view, multi-component, ...) coupling of and transformation between models described in different formalisms; explicitly modelling the often complex, concurrent workflows. Current modelling, analysis and simulation tools support only isolated parts of MPM. The core methods and techniques enabling MPM are modelling language engineering, model operations, and workflow modelling. This paper delves into each enabler, presenting their relation to MPM and how they are supported in our prototype tool: the Modelverse. An automotive power window safety verification example is used to illustrate the Modelverse’s capabilities. All aspects are explicitly modelled and enacted with a Formalism Transformation Graph + Process Model.

A Sequential Statistics Approach to Dynamic Staffing under Demand Uncertainty / Fatemeh S. Hashemi and Michael R. Taaffe (Virginia Tech)

Service systems are highly dependent on staffing decisions to provide satisfactory quality of service. This paper tackles the problem of decision making under uncertainty pertaining to the source of demand. Regardless of the distribution of the demand, the proposed staffing rule reacts to the requested quality of service to determine the quality of the estimators of the unknown demand-process parameters, as well as making optimal staffing decisions. Theoretical results on the consistency and optimality of the proposed method is illustrated using sequential statistics approaches.

Incorporating Abstraction Methods into System-Analysis Integration Methodology for Discrete Event Logistics Systems / Timothy Sprock and Conrad Bock (National Institute of Standards and Technology)

Analysis models, such as discrete event simulation models, are used to support design and operation of discrete event logistics systems (DELS). The time and expertise required to construct these analysis models can be significantly reduced by automatically generating them from formal models of the systems being analyzed. Many analysis models of DELS are constructed from system abstractions, but when the system and analysis are specified at incompatible levels of abstraction, the relationship between the two is imprecise and adhoc. Formal modeling languages, such as those used in object-orientation, make abstraction explicit, simplifying the mappings between system and analysis models and increasing reusability of the integration. We propose fundamental abstractions for DELS and identify corresponding libraries of analysis models. These are used in a system-analysis integration methodology that incorporates abstraction as an explicit step, providing a path to refine those abstractions and model libraries and to generate analysis models from them.

AGENT-BASED SIMULATION / RED ROCK H

Learning and Adaptation

Mohammad Dehghani (NorthEastern University)

Optimizations for Neuron Time Warp (NTW) for Stochastic Reaction-Diffusion Models of Neuron / Mohammad Nazrul Ishlam Patoary and Carl Tropper (McGill University, Canada); Robert McDougal (Yale University, USA); and William W. Lytton (SUNY Downstate Medical Center)

The intracellular calcium signaling pathways of a neuron consist of biochemical reactions along with molecular diffusion. Stochastic discrete event simulation of these pathways provides a more detailed understanding of the pathways than

deterministic simulators because they capture behavior at a molecular level. Our research employs a parallel discrete event simulation simulator, Neuron Time Warp (NTW), which is intended for use for the simulation of neurons. We did not achieve the expected performance of previously derived $\text{Ca}^{(2+)}$ wave model because of an imbalance in computation between the area of the neuron covered by the $\text{Ca}^{(2+)}$ wave and the remaining area of the neuron. In this paper we describe a dynamic load balancing algorithm with a dynamic window control algorithm for NTW. We make use of Q-learning to determine the basic parameters of the algorithm. Using this algorithm we obtained an improvement in the performance of the simulator of up to 30%.

Agent-Based Model Construction Using Inverse Reinforcement Learning / Kamwo Lee, Mark Rucker, William T. Scherer, Peter A. Beling, Matthew S. Gerber, and Hyojung Kang (University of Virginia)

Agent-based modeling (ABM) assumes that behavioral rules affecting an agent's states and actions are known. However, discovering these rules is often challenging and requires deep insight about an agent's behaviors. Inverse reinforcement learning (IRL) can complement ABM by providing a systematic way to find behavioral rules from data. IRL frames learning behavioral rules as a problem of recovering motivations from observed behavior and generating rules consistent with these motivations. In this paper, we propose a method to construct an agent-based model directly from data using IRL. We explain each step of the proposed method and describe challenges that may occur during implementation. Our experimental results show that the proposed method can extract rules and construct an agent-based model with rich but concise behavioral rules for agents while still maintaining aggregate-level properties.

Using Situational Awareness for Adaptive Decision Making in Agent-Based Simulation / Okan Topçu (Middle East Technical University, Northern Cyprus Campus (NCC))

In an agent-based simulation, a plausible decision in a specific context cannot stay be valid in the face of the changing situation. Therefore, the result of the decision making process is mostly related to the agent's situational awareness and its adaptation to the new context and situation of the environment. A sound estimation of the situation requires a clean understanding of the operational domain, not only the data taken from sensors. In this paper, it is aimed to improve decision making by increasing the situational awareness of an agent by incorporating the decision making mechanism with the prior knowledge about the problem domain, such as the existing rules. Specifically, an existing adaptive decision making architecture, which is based on the deliberative coherence theory, is adopted to be driven by situational awareness. Moreover, a case study incorporating unmanned surface vehicles that are aware of the international sea traffic rules is demonstrated.

CYBER-PHYSICAL SYSTEMS / CHARLESTON A

Verification and Validation
Akshay Rajhans (MathWorks)

Efficient Simulation-Based Verification of Probabilistic Timed Automata / Arnd Hartmanns (University of Twente), Sean Sedwards (National Institute of Informatics), and Pedro R. D'Argenio (Universidad Nacional de Córdoba)

Probabilistic timed automata are a formal model for real-time systems with discrete probabilistic and nondeterministic choices. To overcome the state space explosion problem of exhaustive verification, a symbolic simulation-based approach that soundly treats nondeterminism to approximate maximum and minimum reachability probabilities has recently become available. Its use of difference-bound matrices to handle continuous real time however leads to poor performance: most operations are cubic or even exponential in the number of clock variables. In this paper, we propose a novel region-based approach and data structure that reduce the complexity of all operations to being linear. It relies on a particular mapping between symbolic regions and concrete representative valuations. Using an implementation within the Modest Toolset, we show that the new approach is not only easier to implement, but indeed significantly outperforms all current alternatives on standard benchmark models.

Modeling Lessons from Verifying Large Software Systems for Safety and Security / Suresh Kothari and Payas Awadhutkar (Iowa State University), Ahmed Tamrawi (Yarmouk University), and Jon Mathews (EnSoft Corp.)

Verifying software in mission-critical Cyber-Physical Systems (CPS) is an important but daunting task, faced with challenges of accuracy and scalability. This paper discusses lessons learned from verifying properties of the Linux kernel. These lessons have raised questions about traditional verification approaches, and have led us to a model-based approach for software verification. These models are high-level models of the software, as opposed to the prevalent formal methods with low-level representations of software. We use models to gain insights into the challenges of software verification and use those insights to improve software verification. We demonstrate significant advantages of models with a Linux kernel study involving verification of 66,609 Lock instances. We use models to: (a) analyze and find flaws in verification results from LDV, a top-rated Linux verification tool, (b) show significant improvement over LDV by improving accuracy, speed, and by verifying 99.3% instances compared to 65.7% instances by LDV.

ANALYSIS METHODOLOGY / VERANDA B

Rare-event Simulation

Xi Chen (Virginia Tech)

Accurate Computation of the Right Tail of the Sum of Dependent Log-normal Variables / Zdravko Botev (University of New South Wales) and Pierre L'Ecuyer (University of Montreal)

We study the problem of the Monte Carlo estimation of the right tail of the distribution of the sum of correlated log-normal random variables. While a number of theoretically efficient estimators have been proposed for this setting, using a few numerical examples we illustrate that these published proposals may not always be useful in practical simulations. In other words, we show that the established theoretical efficiency of these estimators does not necessarily convert into Monte Carlo estimators with low variance. As a remedy to this defect, we propose a new estimator for this setting. We demonstrate that, not only is our novel estimator theoretically efficient, but, more importantly, its practical performance is significantly better than that of its competitors.

A Joint Gaussian Process Metamodel to Improve Quantile Predictions / Songhao Wang and Szu Hui Ng (National University of Singapore)

Developing metamodels for quantiles can be inaccurate when the input estimates of the quantiles used to fit the model are noisy. In this paper, a multiple response model is developed to jointly model the quantile with a correlated and less-noisy expectation to improve the fit and predictions from the quantile metamodel. We first extend the standard stochastic Gaussian process model to the multi-response case and then use a simple m-design-point example to analytically study the benefits of the joint model over the single model. Several other numerical experiments are also conducted, and the results show that the joint model can provide better performance and thus improve quantile predictions.

Logarithmically Efficient Estimation of the Tail of the Multivariate Normal Distribution / Zdravko Botev, Daniel Mackinlay, and Yi-Lung Chen (University of New South Wales)

Simulation from the tail of the multivariate normal density has numerous applications in statistics and operations research. Unfortunately, there is no simple formula for the cumulative distribution function of the multivariate normal law, and simulation from its tail can frequently only be approximate. In this article we present an asymptotically efficient Monte Carlo estimator for the tail of the multivariate normal distribution. The estimator leverages upon known asymptotic approximations. In addition, we generalize the notion of asymptotic efficiency of Monte Carlo estimators of rare-event probabilities to the sampling properties of Markov chain Monte Carlo algorithms. Regarding these new notions, we propose a simple and practical Markov chain sampler for the normal tail that is asymptotically optimal. We then give a numerical example from finance that illustrates the benefits of an asymptotically efficient Markov chain Monte Carlo sampler.

SIMULATION OPTIMIZATION / PAVILION

Ranking and Selection II

Jeff Hong (City University of Hong Kong)

Optimal Computing Budget Allocation for Ranking the Top Designs with Stochastic Constraints / Hui Xiao and Hu Chen (Southwestern University of Finance and Economics) and Loo Hay Lee (National University of Singapore)

Comparing with the well-studied unconstrained ranking and selecting problems in simulation, literatures on constrained ranking and selection problems are relatively fewer. In this paper, we consider the problem of ranking the top- m designs subjected to stochastic constraints, where the design performance of the main objective as well as the constraint measures can only be estimated from simulation. Using the optimal computing budget allocation framework, we derive an asymptotically optimal allocation rule. The effectiveness of the suggested rule is demonstrated via numerical experiments.

An Efficient Fully Sequential Selection Procedure Guaranteeing Probably Approximately Correct Selection / Sijia Ma and Shane G. Henderson (Cornell University)

Ranking and Selection (R&S) procedures are designed for selecting the best among a finite set of systems using stochastic simulation, guaranteeing the quality of the final selection. Instead of assuming a known lower bound on the difference between the best and others, we consider the probably approximately correct (PAC) selection formulation, which ensures a high quality solution with high probability for all configurations. In this paper, we present a new fully sequential selection procedure, called the Envelope Procedure (EP), which accommodates a variety of sampling rules that, together with a carefully defined termination condition, ensures a PAC selection. A particular sampling rule that achieves good efficiency is proposed. We compare the efficiency of the EP with some existing procedures in numerical experiments, and the results show that the EP saves considerable computational effort in many problem configurations.

A New Framework of Designing Sequential Ranking-and-selection Procedures / Ying Zhong and L. Jeff Hong (City University of Hong Kong)

Many classical sequential procedures model the partial sum difference process between two competing alternatives as a Brownian motion process. In this paper, the marginal probability of eliminating the best alternative is considered while modeling the partial sum difference process. We adaptively allocate the total amount of the probability of incorrect selection to every time point where the comparisons between alternatives are conducted and set the continuation regions to ensure the marginal probability of eliminating the best alternative does not exceed the probability assigned to each time point t . We show by examples that under our framework, the procedure can be easily developed for both indifference-zone (IZ) and IZ free formulations.

HEALTHCARE APPLICATIONS / CHARLESTON C

Simulation in Health Care Scheduling

Idalia Flores (UNAM)

Scheduling Model for Non-Critical Patients Admission into a Hospital Emergency Department / Eva Bruballa (Tomàs Cerdà Computer Science School, Universitat Autònoma de Barcelona); Alvaro Wong and Dolores Rexachs (Universitat Autònoma de Barcelona); Francisco Epelde (Parc Taulí Hospital Universitari, Institut d'Investigació i Innovació Parc Taulí I3PT, Universitat Autònoma de Barcelona); and Emilio Luque (Universitat Autònoma de Barcelona)

The saturation of the Emergency Department services is mostly due to admission of non-urgent or minor-urgency patients who represent a high percentage of admitted patients in the service. We propose a model for scheduling the entry of these non-critical patients into the Emergency Department which may be helpful for the management of the service dealing with the current growing demand for emergency medical care. We hypothesize that a relocation of these non-critical patients in the expected input pattern, initially provided by actual historical data from the hospital, can lead to an improvement in waiting times for all patients, and therefore, to an improvement in the quality of service from the point of view of the service users, as it could avoid long waiting times in the service. Simulation is used to show and evaluate the effect of applying the proposed scheduling model.

Simheuristic of Patient Scheduling Using a Table-Experiment Approach - Simio and Matlab Integration Application / Mohammad Dehghanimohammadabadi (Northeastern University), Mandana Rezaeiahari (State University of New York at Binghamton), and Thomas Keyser (Western New England University)

This paper focuses on optimizing patient scheduling at a breast cancer center for two types of patients: follow up and consult patients. Follow up and consult patients have different service times and follow different care pathways. The objective of this paper is to sequence the patients such that minimum average flow time is achieved for each patient type. A simheuristic framework is developed by integrating MATLAB, Simio, and Excel. Unlike existing simulation–optimization (SO) approaches that target the simulation model controls, this framework tries to optimize a data table in the simulation environment. This simulation evaluation (SE) approach could iteratively input patients arrival table into the simulation model, and obtains the expected performance of the system as a reference to generate the next solution. The obtained results from this framework are further analyzed by comparing five heuristic appointment scheduling methods.

Calibration of a Stochastic Agent-Based Model for Re-Hospitalization Numbers of Psychiatric Patients / Martin Richard Bicher (TU Wien), Christoph Urach (dwh GmbH), Claire Rippinger (DEXHELPP), Günther Zauner (dwh GmbH), and Nikolas Popper (DEXHELPP)

Calibration is a vital part of the modeling and simulation process and denotes the determination of parameter values by estimating them from comparison between simulation results with reference data. During the last decades a lot of algorithms have been developed for this purpose which are able to fit mentioned parameter values generically without information about the modeled system or the simulation. Especially for stochastic simulation models these routines very often require thousands of iterative simulation executions which, in case of large agent-based models, might be too time intensive. In this paper we illustrate a real world example for such a problem and present a solution for it based on probability theory. Hereby we not only calibrate the desired parameters, but also find a measure for the quality of the fit as well. By presenting this example we want to motivate modelers to analyze agent-based models to save costly calibration time.

INTELLIGENT, ADAPTIVE AND AUTONOMOUS SYSTEMS / HILLS

Intelligent, Adaptive and Autonomous Systems: Session 1

Claudia Szabo (University of Adelaide)

Towards Smart Manufacturing with Virtual Factory and Data Analytics / Sanjay Jain (The George Washington University), David Lechevalier (Université de Bourgogne), and Anantha Narayanan (University of Maryland)

Virtual factory models can help improve manufacturing decision making when augmented with data analytics applications. Virtual factory models provide the capability of simulating real factories and generating realistic data streams at the desired level of resolution. Deeper insights can be gained and underlying relationships quantified by channeling the simulation output data to an external analytics tool. This paper describes integration of a virtual factory prototype with a neural network analytics application. The combined capability is used to create a neural network capable of predicting the expected cycle times for a small job shop. The capability can adapt by retraining the neural network whenever the production circumstances change significantly. The trained neural network can be used for functions such as order promising and can support factory management. The analytical and adaptive combination represented by the virtual factory integrated with the neural network thus supports the move towards smart manufacturing.

Heuristics for Planning with Rare Catastrophic Events / Youngjun Kim, Yonatan Gur, and Mykel John Kochenderfer (Stanford University)

High-dimensional Markov decision processes are often solved using online sampling-based methods such as Monte Carlo tree search. Problems that involve rare catastrophic events with large negative rewards can be very challenging for such approaches. The difficulty arises because the common policies for expanding a search tree are not able to handle rare large negative rewards appropriately, leading to high variance estimates of value. This paper studies the impact of reward structure with rare catastrophic events on the performance of common algorithms and proposes enhanced tree policy strategies for Monte

Carlo tree search. Numerical experiments suggest that our proposed methods can significantly improve performance on a variety of problem domains ranging from stochastic multi-armed bandits to aircraft rerouting problems.

A Comparison Analysis of Swarm Intelligence Algorithms for Robot Swarm Learning / Jiaqi Fan (Donghua University), Mengqi Hu (University of Illinois at Chicago), Xianghua Chu (Shenzhen University), and Dong Yang (Donghua University)

In the robot swarm, each robot can freely form swarm with others to share information. Although particle swarm optimization (PSO) has been demonstrated to outperform Q-learning and evolutionary algorithms, less study is conducted to characterize various swarm intelligence (SI) algorithms and evaluate their performances for robot swarm learning. In this research, we select three representative SI algorithms include bat algorithm (BA), PSO, grey wolf optimizer (GWO) according to their learning strategies. These three algorithms are implemented in a distributed manner and compared under various number of robots (NR) and communication ranges (CR). The simulation results demonstrate that: 1) PSO outperforms BA and BA outperforms GWO in general, 2) GWO performs better than PSO and BA under large NR and long CR, 3) increasing NR and CR can significantly improve the performance of GWO. These results can shed lights on selection of optimal SI algorithms for robot swarm under various scenarios.

LOGISTICS, SCM, TRANSPORTATION / SIENA

Scheduling and Dispatching

Klaus Altendorfer (Upper Austrian University of Applied Science)

The Value of Real-Time Data in Stochastic Flowshop Scheduling: A Simulation Study for Makespan / Jose M. Framinan, Paz Perez-Gonzalez, and Victor Fernandez-Viagas (University of Sevilla)

This paper presents an effort to assess how real-time data can be used to re-sequence jobs in a flowshop where processing times are stochastic and the objective is the minimisation of the makespan. By conducting extensive simulation experiments, we try to quantify the advantages of collecting real-time data on the actual completion times of jobs in the shop in order to re-sequence the jobs remaining to be processed. The results show that the benefit of re-sequencing is greatly influenced by the variability of the processing times on the shop floor: There is little advantage when the variability is very high but, for low and intermediate variability levels, re-sequencing provides a way to improve the performance of the initial solution. These results may serve to establish limits on the advantages of using real-time data for improving initial sequencing decisions, at least within the boundaries of our experiments.

Design and Simulation Analysis of PDER: A Multiple-Load Automated Guided Vehicle Dispatching Algorithm / Maojia P. Li and Michael E. Kuhl (Rochester Institute of Technology)

Effective control strategies for automated guided vehicles (AGVs) are important to companies that operate flexible manufacturing systems in terms of maximizing productivity. In this paper, we design and analyze Pickup-or-Delivery-En-Route (PDER), a multiple-load AGV dispatching algorithm. PDER is a task-determination rule that enables a partially loaded vehicle traveling to a drop off destination to pickup and/or drop off loads that the vehicle would otherwise pass by en route to the original destination. We conduct a simulation-based experiment to evaluate the effectiveness of the PDER algorithm. The results indicate that PDER can produce significant positive impacts on throughput and time in system in flexible manufacturing systems utilizing multiple-load AGVs.

Data-Driven Simulation-Based Model for Planning Roadway Operation and Maintenance Projects / Emad Mohamed, Parinaz Jafari, Ming-Fung Siu, and Simaan AbouRizk (University of Alberta)

Snow removal operations are required to maintain roadway safety during snowy winter conditions. Reliable plans outlining the dispatching of plow trucks must be made to deliver snow removal operations on time and within budget. Historical project performance data can be used to inform and facilitate decision-making processes associated with snow removal operations. This research proposes a data-driven simulation framework for planning snow removal projects considering weather and truck-related data collected by real-time sensors. An in-house developed simulation engine, Symphony.Net, is used to simulate operations based on input information extracted from mined sensor data. This model is capable

of simulating plow operations to facilitate planning at both an operational and real-time level. What-if scenarios can be generated to simulate, predict, and optimize project and resource performance. A case study conducted in Alberta, Canada is presented to illustrate the practical application of the proposed method.

LOGISTICS, SCM, TRANSPORTATION / CHARLESTON E

Simheuristics for Logistics, SCM and Transportation (3)

Javier Faulin (Public University of Navarre)

Using Simulation to Estimate Evacuation Times in Large-size Aircrafts: A Case Study with Simio / Pau Estany (Universitat Autònoma de Barcelona), Laura Calvet (Open University of Catalonia - IN3), Pau Fonseca (Universitat Politècnica de Catalunya - BarcelonaTech), and Angel A. Juan (Open University of Catalonia - IN3)

After an emergency landing, it is essential to quickly evacuate the aircraft. Typically, a maximum limit of time is set, which does not depend on the number of passengers on board, the hour (day/night), or the number of inoperative emergency exits. In order to develop strategies and protocols for efficient evacuations, it is important to define all the characteristics of the aircraft, analyze multiple scenarios that may arise, conduct a comprehensive study of passengers' behavior, and consider external factors that may affect the evacuation time. Nowadays, there are flexible and powerful object-oriented simulation tools that enable the creation of realistic models, which are useful to assess evacuation strategies by studying different scenarios. In this context, this paper presents a model to analyze realistic scenarios for the evacuation of the Airbus 380, which must be done in less than 90 seconds.

A Simheuristic Approach for Freight Transport in Sustainable and Smart Cities / Lorena Silvana Reyes-Rubiano (Public University of Navarra), Laura Calvet (Open University of Catalonia), Javier Faulin (Public University of Navarra), and Angel Juan (Open University of Catalonia)

In modern society, sustainable transportation practices in smart cities are becoming increasingly important for both companies and citizens. These practices constitute a global trend, which affects multiple sectors placing relevant socio-economic and environmental challenges. Moreover, uncertainty plays a crucial role in transport activities, e.g., traveling time may be affected by road works, the weather, or accidents, among others. This paper addresses a rich extension of the capacitated vehicle routing problem, which considers sustainability indicators (i.e., economic, environmental and social impacts) and stochastic traveling times. A simheuristic approach integrating Monte Carlo simulation into a multi-start metaheuristic is proposed to solve it. A computational experiment is carried out to validate our approach, and analyze the trade-off between indicators and the effect of stochasticity on the solutions.

Designing Internal Supply Routes: A Case Study in the Automotive Industry / Marcelus Fabri and Helena Ramalinho (Universitat Pompeu Fabra)

In today's competitive market environment, logistics has a substantial impact on companies' performance. Improving the logistics efficiency is a main goal for many industries, especially, for those involved in car manufacturing. This work considers a real logistics problem in a car-assembly factory. The problem consists in optimizing the supply of components from the internal warehouse to the production lines, determining the best delivering routes. We describe the problem in detail, propose a mathematical programming model, and solve it with CPLEX. Afterward, to evaluate the impact of implementing the optimal routes in realistic scenarios, we apply Monte Carlo simulation and present a comparison between both solutions. The manufacturer's Key Performance Indicators are considered for evaluating the obtained results. The study showed that the proposed solution outperformed the current one, pointing out that the optimized routes could deal with different levels of production in a more efficient and cost reductive manner.

MASM / VERANDA E

Dispatching and Scheduling Methods

Andreas Klemmt (Infineon Technologies Dresden GmbH)

Scheduling Strategy of Semiconductor Production Lines with Remaining Cycle Time Prediction / Li Li and Qingyun Yu (Tongji University)

With the rapid development of semiconductor manufacturing, customers' demand for on-time delivery rate (ODR) makes scheduling strategies face new challenges. In order to meet customers' delivery requirements, scheduling strategies generally need to comprehensively consider remaining cycle time (CT), ODR, movement (MOV) speed and machine load balancing. In order to solve these problems, this paper proposed a scheduling strategy of semiconductor production lines with remaining cycle time prediction. Firstly, gather features related to performance index and then filtrate them through dimension reduction method. Secondly, use the above feature subset to build remaining cycle time prediction model by random forest algorithm. Next, design the scheduling strategy of semiconductor production lines with remaining cycle time prediction. Finally, make simulation experiments to verify the effectiveness of the proposed scheduling strategy. Simulation results show that the proposed scheduling strategy can improve the mean CT, throughput (TH), machine utilization time (MUT) and ODR in different extant.

From Dispatching To Scheduling: Challenges in Integrating a Generic Optimization Platform into Semiconductor Shop Floor Execution / Andreas Klemmt, Jens Kutschke, and Christian Schubert (Infineon Technologies Dresden GmbH)

This paper shows how automatic optimization of scheduling problems has been integrated within the automation framework of a semiconductor factory. Special attention is paid to the requirements arising from such an application in real world production in terms of constraints and objectives as well as from a factory integration perspective such as autonomous operation, high availability and efficient maintenance. Subsequently, possible solutions on how such requirements can be addressed will be discussed. Thereby, the advantage of using Constraint Programming solvers is highlighted. Knowledge that was gained during the implementation is presented for selected cases followed by the benefits that were achieved.

MANUFACTURING APPLICATIONS / CHARLESTON B

Simulation & Data Analytics

Camilla Lundgren (Chalmers University of Technology)

A VSM Approach to Support Data Collection for a Simulation Model / Maja Viktoria Linnea Barring, Daniel Nåfors, Daniel Henriksen, David Olsson, and Björn Johansson (Chalmers University of Technology) and Ulrika Larsson (RUAG Space Group)

Simulation is a powerful tool to analyze and help in the decision making process of a production system. It is capable of delivering a dynamic analysis, both of the existing system and the future planned system. One major challenge with simulation projects however, is the time required at the initial stage when collecting data. For this study, Value Stream Mapping (VSM) has been selected as a complementary method for the data collection. VSM has been widely spread in industry, and it is a suitable method for identifying value streams and visualizing flows. In this study, the applicability of VSM for data collection is examined for a production system with complex and non-linear flows. The results of this study confirms that VSM can support in the data collection phase, but entails the support from subject matters.

Integrating Data Analytics and Simulation for Defect Management in Manufacturing Environments / Faisal Aqlan (Penn State Behrend), Sreekanth Ramakrishnan (IBM Corporation), and Abdulrahman Shamsan (Binghamton University)

Defect management in manufacturing environments requires effective identification of the defects and finding proper solutions to resolve them. Predicting and preventing the defects before they can occur is the focus of quality risk management. To effectively manage defects, companies need to analyze historical data to identify the causes and solutions for defects as well as study the impact the defect can have on the processes, priorities, and operations. This

study integrates data analytics and simulation modeling to develop a system for defect management in manufacturing environments. Simulation is used to analyze the behavior of the system whereas data analytics is used to develop prediction models for defect resolution. A case study from high-end server manufacturing environment, which is characterized by extensive test processes to ensure high quality and reliability of servers, is provided. The proposed approach helps decision makers analyze and manage defects and develop proactive means to prevent them.

Knowledge Discovery and Robustness Analysis in Manufacturing Simulations / Niclas Feldkamp, Soeren Bergmann, and Steffen Strassburger (Ilmenau University of Technology) and Thomas Schulze (Otto-von-Guericke-University Magdeburg)

Discrete event simulation is an established methodology for investigating the dynamic behavior of complex manufacturing and logistics systems. Traditionally, simulation experts conduct experiments for predetermined system specifications focusing on single model aspects and specific analysis questions. In addition to that, the concept of data farming and knowledge discovery is an ongoing research issue that consists of broad scale experimentation and data mining assisted analysis of massive simulation output data. As an extension to this approach, we propose a concept for investigating the robustness of complex manufacturing and logistic systems which are often very sensitive to variation and noise. Based on Taguchi's loss function, we developed a concept including data farming and visual analytics methodologies to investigate sources of variation in a model and the factor values that make a configuration robust. The concept is demonstrated on an exemplary case study model.

SIMULATION EDUCATION / VISTAS

Humans, Education and Simulation

Saikou Diallo (Virginia Modeling, Analysis and Simulation Center)

Incorporating Sound in Simulations / Justin Deuro, Christopher J. Lynch, Hamdi Kavak, and Jose J. Padilla (Old Dominion University)

In this paper, we raise the questions: how could sound influence the usability of simulations? How could sound influence the learning of simulation creation? How could sound support processes like verification? We argue that sound can support learning by relying on music/sound cues' emotional engagement on users and verification by providing insight into the correctness of simulation execution during runtime. For instance, sound cues could indicate when certain events occur and if processes in a simulation are operating within their specifications. We explore potential benefits and challenges posed by incorporating sound into DES models. Many perceived challenges of this incorporation overlap with known visualization challenges for conveying information during runtime, as both cases deal with conveying sensory stimuli. We present conceptual examples and report on ongoing efforts to integrate sound into a DES simulation environment.

Agent-based Simulation for Teaching Ethics / Ruth Isabel Murrugarra (Universidad Adolfo Ibañez) and William Allan Wallace (Rensselaer Polytechnic Institute)

The present work discusses the use of NetLogo, an agent-based simulation software, as a tool to teach ethics modeling as part of an ethics course. It allows students to define and describe the behavioral rules of agents under different ethical theories through agent-based simulation and learn and assess the consequences of such ethical behaviors. Several simulations developed by the students along with their principal findings are presented.

CASE STUDIES / CHARLESTON D

Homeland Security

Edward Williams (PMC)

Modeling and Simulation of Port-of-entry Systems / Weiwei Chen, Benjamin Melamed, and Mingfei Teng (Rutgers Business School – Newark and New Brunswick) and Christopher Canaday (U.S. Customs and Border Protection)

This paper describes a suite of simulation models for Port-of-Entry (POE) systems, dubbed POESS (POE Simulation System). POESS was developed with the support of the U.S. Department of Homeland Security (DHS) for use primarily by the U.S. Customs and Border Protection (CBP) agency. POESS

aims to assist CBP in POE design and operational decision making. A POESS simulation model of the Bridge of the Americas (BOTA) POE, located at El Paso, Texas, is described as an example.

***Simulation of Performance Based Services in Disaster Response Operations* / Arnd Schirrmann (Airbus)**

Performance-based services are an interesting concept for partnerships between governmental organizations and the private sector to meet requirements in terms of budget plannability and service level guarantees. This paper discusses the use of simulation in the process of defining the technical and contractual configuration of those services with a case study in airborne services in disaster response operations. The simulation helps to overcome the limitations of analytical methods in modelling complex operational scenarios and logistics strategies.

***Clustering People Trust Behavior in Emergency Evacuation: Evidence from Sinabung Volcano Eruption* / Hilya Mudrika Arini, Tim Bedford, John Quigley, and Calvin Burns (University of Strathclyde)**

Sinabung is one of the volcanoes in Indonesia which commands government and societal attention since its first eruption in 2010. In contrast to other volcanoes, Sinabung volcano is still on the warning level up to and including the present time. According to the prior interview conducted to 14 participants from local government and local leaders in Medan and Karo, Indonesia, the long duration of warning level encourages some people to behave differently and become complacent. People who initially trusted the government in the 2010 eruption currently doubt and distrust the government information and instruction. This study aims to compare the result from the prior interview and survey in order to categorize and cluster people regarding their trust behavior by using a Situational Judgment Test. This clustering result can be utilized as a foundation to build a conceptual model of trust behavior in Agent-Based Modeling and Simulation (ABMS) for further research.

CASE STUDIES / VERANDA D

Logistics

Jonatan Berglund (Chalmers University of Technology)

***Simulating Recovery Strategies to Enhance the Resilience of a Semiconductor Supply Network* / Yilin Chen, Thomas Ponsignon, Roland Weixlgartner, and Hans Ehm (Infineon Technologies AG)**

Enhancing supply chain resilience is of vital importance in today's business to manage and mitigate the risks, especially in the semiconductor industry challenged with intrinsic long cycle times and short product life-cycles. Transferring production from a primary site to an alternative site after a disaster is one of the strategies to ensure resilience of the supply network. In this study, different types of alternative sites with various levels of preparedness are investigated. A discrete-event simulation is used to evaluate their operational and financial impacts under four different disruption scenarios. The simulation outcomes demonstrate unexpected positive benefits of various alternative sites in terms of fast recovery and resilience building.

***Integrating Campus Operations Decision Support Models at the National Institutes of Health (NIH)* / Antonio R. Rodriguez and Joseph J. Wolski (National Institutes of Health)**

At the National Institutes of Health (NIH), a federal agency supporting basic biomedical research, decision makers are faced with the challenge of identifying ways to improve the efficiency and effectiveness of research support services and challenges of doing "more with less" resources. The Office of Research Services (ORS), Office of Quality Management (OQM) provides support in solving these challenges through development of the Campus Operations Decision Support (CODS) simulation model. The model consists of a variety of software tools and techniques to model a campus 3D "virtual world" that can be used in a variety of applications to better understand and enhance the delivery of services to support the research mission at NIH. The project includes sub-models that aid in analyzing pedestrian and traffic movement onto and within the campus, visitor screening, the NIH shuttle bus network, and provides for future extensibility to additional research support activities.

Hierarchical Simulation Modelling Of Distribution Centers / Dusan Sormaz and Mandvi Malik (Ohio University)

Order picking is the most expensive operation in a distribution center. Due to a large amount of labor used in order picking, the cost associated with the labor is high. The objective of this paper is to build a simulation model that would help distribution center managers to forecast their throughput by optimizing the worker configuration. The research uses a hierarchical approach to build a simulation model. The simulation model is divided into small submodels. The submodels are completely independent of each other. The submodels can be combined to make various different complete models. In this research, the submodels are used to build a simulation model of an actual industrial distribution center. The model is then run for twenty-four hours and the results are compared with the flat simulation model of the same distribution center.

CASE STUDIES / CHARLESTON F

Manufacturing 2

Anders Skoogh (Chalmers University of Technology)

Simulation Analysis of Processing Complexity and Production Variety in Automated Manufacturing System / Hayder Zghair (Kettering University) and Ahad Ali (Lawrence Tech University)

The objective of this research work is to identify resources needed to stabilize a partially automated system that runs multi-options product (MOP), the production variety has been planned to include the following products OP1, PO2, OP3, and OP4. The problem is to trading-off between two scenarios that finds an optimal setup of automated processing resources realizing highest throughput and working accordingly with the capacity of non-automated ones. A set of processing cycles is examined investigating the impact on the system throughput along with simulation experiments using Rockwell software. Because of the shortage in capacity of the non-automated processes and budget restrictions to adopt fully automated processes, OP1 directly goes out of the system after the automated processes. Results show many opportunities to improve the automated processes optimizing the capacity of the resources without adoption the full automation system

Verification and Validation of Shipyard Logistics Simulation System and its Use Case Identification / Yong-Kuk Jeong, Hui-Qiang Shen, SeungHoon Nam, Youngmin Kim, and Jong-Gye Shin (Seoul National University); Philippe Lee (Xinnos Co., Ltd.); and Jae Ho Choi and Jong Hun Woo (Korea Maritime and Ocean University)

Simulation systems for analyzing the logistics process occurring in the shipyard have been studied by many researchers. However, there was a lack of research on how to verify simulation results and how to use these systems continuously. Therefore, in this study, we proposed a method to verify and validate a logistics simulation system developed in our previous research. In addition, use cases were divided into simulation and planning aspects in order that the shipyard could use the system continuously. Verification methods and use cases proposed in this paper were studied in cooperation with large shipyards in South Korea.

CraftBrew: Experiences of Developing a Low-Cost Brewery Manamgement System with Cloud-Based Simulation / Simon J. E. Taylor, Anastasia Anagnostou, and David Bell (Brunel University London) and Shane Kite and Gary Patterson (Saker Solutions)

This paper describes on-going work that aims to support decision making in the Craft Brewing, or Microbrewing, industry, a major SME sector in Europe and North America. The aim is to assist Craft Brewers to ensure that their products are consumed in an optimum time window. We previously demonstrated how cloud-based simulation could provide low cost access to simulation using a template approach based on the CloudSME Simulation Platform. In this paper we give an overview of CraftBrew, the whole brewery management system that we are building around the cloud-based simulation approach to support other aspects of the brewing process.

Tuesday 3:30p.m.-5:00p.m.**HISTORY OF SIMULATION / TRAILS****History of Simulation Modeling**

Tony Yaacoub (Georgia Institute of Technology)

History of Verification and Validation of Simulation Models / Robert G. Sargent (Syracuse University) and Osman Balci (Virginia Tech)

This paper gives the history of verification and validation of discrete-event simulation models as seen through the eyes of its authors and their experiences. The history is divided into three time periods: the early era covering years up to 1970, the awareness era covering the years of the 1970's and 1980's, and the modern era covering the years of 1990 to the present.

The History of Simulation Modeling / Stephen Roberts (North Carolina State University) and Dennis Pegden (Simio, LLC)

During the past half-century simulation has advanced as a tool of choice for operational systems analysis. The advances in technology have stimulated new products and new environments without software standards or methodological commonality. Each new simulation language or product offers its own unique set of features and capabilities. Yet these simulation products are the evolution of research, development, and application. In this paper we interpret the historical development of simulation modeling. In our view simulation modeling is that part of the simulation problem-solving process that focuses on the development of the model. It is the interpretation of a real production (or service) problem in terms of a simulation language capable of performing a simulation of that real-world process. While "interpretation" is in the "eyes of the beholder" (namely us) there are some historical viewpoints and methods that influence the design of the simulation model.

FUTURE OF SIMULATION / VERANDA A**Panel: Computing Challenges & Opportunities in Modeling & Simulation**
Dong Jin (Illinois Institute of Technology)*Computational Challenges in Modeling & Simulation of Complex Systems* / Richard Fujimoto (Georgia Institute of Technology), Christopher Carothers (Rensselaer Polytechnic Institute), Alois Ferscha (Johannes Kepler University Linz), David Jefferson (Lawrence Livermore National Laboratory), Margaret Loper (Georgia Tech Research Institute), Madhav Marathe (Virginia Tech), and Simon J. E. Taylor (Brunel University London)

Modeling and simulation faces many new computational challenges in the design of complex engineered systems. The systems that need to be modeled are increasingly interconnected and interdependent, achieving unprecedented levels of complexity. The computational platforms upon which simulations execute have undergone dramatic changes in recent years. Position statements by leading researchers are presented concerning important computational challenges and opportunities facing the M&S community.

INTRODUCTORY TUTORIALS / RED ROCK G**Tutorials on System Dynamics and The Tao of Simulation**

Anastasia Anagnostou (Brunel University)

System Dynamics: a Soft and Hard Approach to Modelling / Martin Kunc (University of Warwick)

System Dynamics (SD) can be employed for qualitative and quantitative modeling. There are important tools and methods within SD that can be easily accommodated within qualitative modeling, also known as Soft Operational Research or problem structuring method. While traditional stocks and flows are the basic components of quantitative SD modeling, quantitative SD modeling shares many commonalities, e.g. empirically driven, thorough testing, and critical focused to outputs, with traditional simulation methods and quantitative Operations Research tools. This tutorial informs novice modelers on the aspects to consider when they want to use SD as a qualitative and quantitative modeling method. In any approach employed, the use of SD modeling needs to be grounded in relevant literature from the perspective employed, qualitative or quantitative.

***The Tao of Simulation* / Lee Schruben and Abhinav Adduri (UC Berkeley)**

This paper introduces an open-source, cross-platform object called Tao to the simulation community for teaching and research. Tao is simple enough to begin using within minutes, but is extensible and interoperable with powerful statistical, graphical, animation, and simulation software, as well as internet-of-things hardware. Tao runs locally or remotely in a web browser, freeing it from OS constraints to integrate simulation engines directly into application-specific websites. Modeling examples presented here include a chemical reaction, time-bound activity sequences, and an embedded simulation for real-time load balancing. To illustrate using Tao for research, Hyden's, single-run, global optimization algorithm was implemented. This extension enables Tao to optimize the design of dynamic systems such as queueing networks and supply chains in a single run. To demonstrate Tao's extensibility, the innovations of pending-intervals and a bioproduction stochastic scheduling algorithm were implemented.

MODELING METHODOLOGY / RED ROCK I**DEVS Applications**

Fernando Barros (University of Coimbra)

***An Approach for DEVS Based Modeling of Electrical Power Systems* / Angelionel Toba, Mamadou Seck, Matthew Amissah, and Sarah Bouazzaoui (Old Dominion University)**

The size and complexity of modern power systems, as well as emergent technologies and the uncertainty in energy planning, make the design and engineering of these systems challenging. One of the main challenges is the development of models that adequately capture the complex relationships between the components of these systems. We present a DEVS (Discrete Event System Specification) based framework for modeling a power system for energy planning. DEVS preserves the hierarchical and modular construction properties of a system (Chow and Zeigler 1994). That is, it enables each of the components of the system to be modeled separately, as well as the representation of the multilayer architecture of that system. As a proof of concept, we present a power system model, simulating the deployment of energy sources, on the PyPDEVS platform (Van Tendeloo and Vangheluwe 2015), considering dispatcher, unit commitment, load, generation, storage and transmission lines components.

***A Cell-DEVS Model for Fracture Propagation in Rock* / Gabriel Wainer and Scott Stewart (Carleton University)**

We present a cellular model to study the propagation of cracks in a given sample of rock. The model uses the fractal geometry found in real rocks and the stress and strain on an element of rock to update the element's strength. We study the propagation speed of the cracks with different initial conditions. The model shows that the more inhomogeneous a rock sample is the quicker a fracture can propagate through it. Because fractures release a large amount of energy when they grow, earthquakes are more likely to occur in these situations.

***Hierarchical Markov Decision Process Based on Devs Formalism* / Céline Kessler, Laurent Capocchi, and Jean Francois Santucci (SPE UMR CNRS 6134) and Bernard Zeigler (RTSync Corp.)**

Markov decision processes (MDPs) have proven useful as models of stochastic planning and decision problems. To try to propose practical implementation of MDPs, hierarchical methods are often used in MDPs or reinforcement learning to delegate the optimization of the total problem to simpler hierarchical sub-problems. The goal of the paper is to propose a generic discrete-event based software Framework allowing to use hierarchical MDPs and reinforcement Learning to solve planning or decision problems. The proposed approach has been validated using the "grid world" typical MDP use case.

AGENT-BASED SIMULATION / RED ROCK H**Agent-Driven Experiment Management and Modeling**

Alice E. Smith (Auburn University)

***Model Alignment Using Optimization and Design of Experiments* / Alejandro Teran, Alice E. Smith, and Levent Yilmaz (Auburn University)**

The use of simulation modeling for scientific tasks demands that these models be replicated and independently verified by other members of the scientific

community. However, determining whether two independently developed simulation models are “equal,” is not trivial. Model alignment is the term for this type of comparison. In this paper, we present an extension of the model alignment methodology for comparing the outcome of two simulation models that searches the response surface of both models for significant differences. Our approach incorporates elements of both optimization and design of experiments for achieving this goal. We discuss the general framework of our methodology, its feasibility of implementation, as well as some of the obstacles we foresee in its generalized application.

Models as Self-Aware Cognitive Agents and Adaptive Mediators for Model-Driven Science / Levent Yilmaz, Sritika Chakladar, Kyle Doud, Alice E. Smith, and Alejandro Teran-Somohano (Auburn University) and Halit Oguztuzun, Sema Cam, Orcun Dayibas, and Bilge Kaan Gorur (Middle East Technical University)

There are often concerns about the reliability of simulation results due to improper design of experiments, limited support in the execution and analysis of experiments, and lack of integrated computational frameworks for model learning through simulation experiments. Such issues result in flawed analysis as well as misdirected human and computational effort. We put forward a methodological basis, which aims to (1) explore the utility of viewing models as adaptive agents that mediate among domain theories, data, requirements, principles, and analogies, (2) underline the role of cognitive assistance for model discovery, experimentation, and evidence evaluation so as to differentiate between competing models and to attain a balance between model exploration and exploitation, and (3) examine strategies for explanatory justification of model assumptions via cognitive models that explicate coherence judgements.

A Framework for Formal Automated Analysis of Simulation Experiments using Probabilistic Model Checking / Kyle Doud and Levent Yilmaz (Auburn University)

Simulation experiments contribute to scientific discovery due to the degree and extent of reproducibility that simulation systems provide. On the other hand, domain scientists may lack expertise in simulation programming and the use of effective methods for instrumenting, evaluating, and comparing models. By utilizing formal automated verification methods, we aim to improve the process of evaluating model assumptions against evidence, and to facilitate selection of new hypotheses to maximize information gain while reducing information processing requirements. To this end, to evaluate the results of a simulation experiment against expected regularities, a probabilistic model checking system is coupled with a Domain-Specific Language that expresses abstract finite state verification properties. These specification patterns are evaluated against the run-time Discrete-Time-Markov Chain model abstracted from the data obtained through aspect-driven automated instrumentation.

AGENT-BASED SIMULATION / VERANDA D

Logistics and Transportation Infrastructure

Dave Goldsman (Georgia Institute of Technology)

An Agent-Based Simulation Model for Autonomous Trailer Docking / Berry Gerrits, Martijn R.K. Mes, and Peter C. Schuur (University of Twente)

This paper presents a simulation model of a generic automated planning and control system for the pick-up and docking of semi-trailers by means of autonomous Yard Tractors (YTs) in a collision- and conflict free environment. To support the planning and control of the YTs, we propose a Multi-Agent System (MAS). We illustrate our approach using a case study at a Dutch logistics service provider. To evaluate the proposed system, we design an agent-based simulation model, which is set up in a similar way as the MAS. We conclude with the verification and validation of the simulation model.

An Agent-based Simulation Model for Distributed Vehicle Sharing Operations / Mengqi Hu and Yang Chen (University of Illinois at Chicago) and Xiaopeng Li and Kaiqi Xiong (University of South Florida)

Vehicle sharing can increase the efficiency of transportation infrastructures and improve environmental sustainability. A distributed operation model is needed to improve a vehicle's intelligence and autonomy. In this research, we develop an agent-based simulation model for a linear transportation system to evaluate three different vehicle sharing operations that include: 1) an independent operation where vehicles are isolate, 2) a centralized operation which assumes a central

supervisor agent controls all the vehicles, and 3) a distributed operation where vehicles can communicate with others and make decisions by themselves. Our simulation results demonstrate that: 1) the centralized and distributed models are significantly better than the independent model for large car capacity, 2) centralized model performs significantly better than the distributed model for large car capacity and small communication range, and 3) the distributed model can perform better than the centralized model for large car capacity and communication range.

CYBER-PHYSICAL SYSTEMS / CHARLESTON A

Control of CPS

Akshay Rajhans (MathWorks)

Designing Highway Access Control System Using Multi-Class M/G/C/C State Dependent Queueing Model and Cross-Entropy Method / Yifan Wang, Daniel Kim, and Seong-Hee Kim (Georgia Institute of Technology) and Haengju Lee (DGIST)

In this paper, we consider a futuristic scenario where there exists a special lane in a segment of a highway; vehicles which wish to use the lane must send access requests ahead of time; and only the vehicles whose requests are accepted can use the lane. Vehicle classes are defined by vehicle sizes and carry a different number of passengers. Our goal is to find an optimal allocation of the lane capacity among different vehicle classes maximizing the long-run average passenger throughput. We use a multi-class M/G/C/C state dependent model to calculate the long-run average passenger throughput for a given allocation and use a cross-entropy method to find an optimal allocation among a large number of possible allocations. We discuss how this problem formulation is applicable to general resource sharing problems and discuss how to dynamically control acceptance/rejection of access requests to further enhance the real-time efficiency of our system.

A SimEvents Model For Hybrid Traffic Simulation / Yue Zhang and Christos G. Cassandras (Boston University) and Wei Li and Pieter J. Mosterman (MathWorks)

Intelligent transportation systems are typical Cyber-Physical Systems (CPS) that combine physical components with cyber elements that include communication, information processing and control mechanisms for Connected Automated Vehicles (CAVs). To test and evaluate the efficiency of such systems, new simulation platforms are needed. In this paper, a SimEvents-based framework is introduced for hybrid traffic simulation at the microscopic level. This framework enables users to apply different control strategies for CAVs and carry out performance analysis of proposed algorithms by authoring customized discrete-event and hybrid systems based on MATLAB Discrete-Event System using object-oriented MATLAB. The framework spans multiple toolboxes including MATLAB, Simulink, and SimEvents.

ANALYSIS METHODOLOGY / VERANDA B

Metamodeling

James R. Thompson (MITRE Corporation)

A Stochastic Simulation Calibration Framework for Real-time System Control / Wei Xie and Pu Zhang (Rensselaer Polytechnic Institute) and qiong zhang (Virginia Commonwealth University)

A simplified stochastic simulation model is often used to guide real-time decision making for a complex real system, such as scheduling decisions for semiconductor production. To provide reliable guidance, we propose a simulation calibration framework. We first develop a spatial-temporal metamodel to estimate the system dynamic behaviors at different settings of calibration parameters. Then, assisted by the metamodel, we introduce a calibration model so that the dynamic behaviors of the calibrated simulation model match with those of the real system. Thus, for any feasible decisions, the calibrated simulation model can predict the future outputs for the real system and deliver prediction intervals.

Metamodeling a Systems Dynamics Model: A Contemporary Comparison of Methods / Rodrigo Andres De la Fuente (University of Concepcion) and Raymond Lester Smith (East Carolina University)

Advancements in computer technology have resulted in improved computing

capability and software functionality. Concurrently, in the simulation community demand to study complex, integrated systems has grown. As a result, it is difficult to perform model exploration or optimization simply due to time and resource limitations. Metamodeling offers an approach to overcome this issue; however, limited study has been made to compare the methods most appropriate for simulation modeling. This paper presents a contemporary comparison of methods useful for creating a metamodel of a simulation model. For comparison we explore the performance of a complex system dynamics model of a community hospital. In our view several characteristics of hospital operations present an interesting challenge to explore and compare the well-known competing methods. We consider three dimensions in our comparison: fit quality, fitting time, and results interpretability. The paper discusses the better performing methods corresponding to these dimensions and considers tradeoffs.

A Misspecification Test for Simulation Metamodels / Shiyu Wang, Guangwu Liu, and Kun Zhang (City University of Hong Kong)

In this paper we propose a novel misspecification test for simulation metamodels. It is a consistent test that helps to assess the adequacy of simulation metamodels. The test statistic we construct is shown to be asymptotically normally distributed under the null hypothesis that the metamodel is correct, while diverging to infinity at a rate of \sqrt{n} , where n is the test sample size if the given metamodel is inadequate. Furthermore, as a by-product, we construct confidence intervals for mean squared errors of the metamodels. Preliminary numerical studies show that the test works quite well and has good finite-sample properties.

SIMULATION OPTIMIZATION / PAVILION

Simulation Optimization with Input Uncertainty
Eunhye Song (Penn State University)

Ranking and Selection under Input Uncertainty: A Budget Allocation Formulation / Di Wu and Enlu Zhou (Georgia Institute of Technology)

A widely acknowledged challenge in ranking and selection is how to allocate the simulation budget such that the probability of correction selection (PCS) is maximized. However, there is yet another challenge: when the input distributions are estimated using finite real-world data, simulation output is subject to input uncertainty and we may fail to identify the best system even using infinite simulation budget. We propose a new formulation that captures the tradeoff between collecting input data and running simulations. To solve the formulation, we develop an algorithm for two-stage allocation of finite budget. We use numerical experiment to demonstrate the performance of our algorithm.

Robust Simulation Based Optimization with Input Uncertainty / Sathishkumar Lakshmanan and Jayendran Venkateswaran (IIT Bombay)

Simulation-based Optimization (SbO) assumes that the simulation model is valid, and that the probability distributions used therein are accurate. However, in practice, the input probability distributions (input models) are estimated by sampling data from the real system. The errors in such estimates can have a profound impact on the optimal solution obtained by SbO. The existing two-stage framework for SbO under computational budget constraint considers only the stochastic uncertainty. In our variant, we consider the input model parameter uncertainty as well. Our algorithmic procedure is based on the stochastic kriging metamodel-assisted bootstrapping with an efficient global optimization technique which sequentially searches the optimum and incorporates Optimal Computational Budget Allocation (OCBA). This framework is also used for determining tighter worst case bounds of the SbO with input uncertainty. The proposed framework is illustrated with the M/M/1 queuing model.

Bayesian Simulation Optimization with Input Uncertainty / Michael Arthur Leopold Pearce and Juergen Branke (University of Warwick)

We consider simulation optimization in the presence of input uncertainty. In particular, we assume that the input distribution can be described by some continuous parameters, and that we have some prior knowledge defining the probability distribution for these parameters. We then seek the simulation design that has the best expected performance over the possible parameters of the input distributions. Assuming correlation of performance between solutions and also between input distributions, we propose modifications of two well-known simulation optimization algorithms, Efficient Global Optimization and Knowledge Gradient with Continuous Parameters, so that they work efficiently under input uncertainty.

HEALTHCARE APPLICATIONS / CHARLESTON C

Health Care Operations

Niki Popper (Vienna University of Technology)

Modeling and Simulating Hospital Operations in a 3D Environment / Fraser L. Greenroyd (Loughborough University), Rebecca Hayward (BuroHappold Engineering Ltd.), Andrew Price and Peter Demian (Loughborough University), and Shrikant Sharma (BuroHappold Engineering Ltd.)

The use of dashboards to aid hospital decision makers in managerial and clinical decisions is well documented in the literature, though few broach the challenging subject of combining cost measurement with user satisfaction and building layout optimization. This paper presents an innovative dashboard in a 3D environment, providing decision makers with simulation capabilities using agent based simulation, allowing examination of their facility and the impact of policy, process and layout changes on patients and finances. An example is presented for an Emergency Department, wherein the presented dashboard revealed that the costs of constructing additional triage rooms would produce no benefit to patients; rather, a change in the process would be more beneficial compared with the existing situation. It is concluded that the developed dashboard allows users to make comparisons between multiple scenarios and visualize data in an intuitive format, allowing for decision makers to optimize their facility and operations.

Reducing Capital Cost and Semi-Private Bed Experience By Simulating Hospital Inpatient Operations / Martin J. Miller (Decision Analytics)

Hospital planners want to build the right capacity based on expected demand. Overbuilding means overspending and building beds that become underutilized. Underbuilding means insufficient beds, causing longer bed queues. Placing inpatients in semi-private beds reduces capital investment cost by building fewer rooms, or potentially fewer floors, but this option usually reduces patient satisfaction compared to placing inpatients in all private beds. Additionally, studies show inpatients with private bed experience have shorter lengths of stay. This paper describes how simulation modeling can help reduce capital costs by determining an appropriate number of semi-private rooms that ensure sufficient capacity yet care for most inpatients with a private room experience. Results from a recent inpatient simulation project indicates possible reduction of private rooms by 25 percent yet only requiring inpatient placement in semi-private beds 5 percent of time. Further analysis shows this result is only possible when inpatient capacity is precisely determined.

Simulation-based Design and Traffic Flow Improvements in the Operating Room / Amin Khoshkenar, Kevin Taaffe, Miranda Muhs, Lawrence Fredendall, and Yann Ferrand (Clemson University); Dee San (MUSC Health); and Anjali Joseph (Clemson University)

A simulation model was created to model the traffic flow in the operating room. A key research challenge in operating room design is to create the most efficient layout that supports staff and patient requirements on the day of surgery. The simulation allows comparison of base model designs to future designs using several performance measures. To develop the model, we videotaped multiple surgeries in a set of operating rooms and then coded all activities by location, agent and purpose. Our current analysis compares layouts based on total distance walked by agents, as well as the number of contacts, measured as the number of times agents must change their path to accommodate some other agent or physical constraint in the room. We demonstrate the value and capability of the model by improving traffic flow in the operating room as a result of rotating the bed orientation.

INTELLIGENT, ADAPTIVE AND AUTONOMOUS SYSTEMS / HILLS

Intelligent, Adaptive and Autonomous Systems: Session 2

Claudia Szabo (University of Adelaide)

Discrete Event Simulation of a Road Intersection Integrating V2V and V2I Features to Improve Traffic Flow / Ben Benzaman and Deepak Sharma (Montana State University)

Traffic congestion leads to waste of time and has tremendous impact on the environment. To reduce traffic congestion, vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication have been explored and implemented.

This paper focuses on integrating features of gap acceptance behavior proposed in V2V and road segment occupancy & intelligent traffic light phasing of V2I. Three separate simulation models have been presented in this study. A design of experiment generated thirty scenarios to capture the overall traffic flow performance in terms of total time and waiting time in the system, WIP and system efficiency. Results revealed that the proposed V2I simulation model in which routing was based on traffic light availability decreased the waiting time, total time and WIP significantly compared to baseline and smart traffic light vehicle flow model. The routing principle in the latter two models was based on space availability approach.

A Tool for Mining Discrete Event Simulation Model / Yan Wang and Grégory Zacharewicz (IMS, University of Bordeaux); Mamadou Kaba Traoré (LIMOS, University of Blaise Pascal); and David Chen (IMS, University of Bordeaux)

Mining a discrete event simulation model from data has always been a big challenge, which is related to the problem of system inference in systems theory. D2FD (Data to Fuzzy–DEVS model) method can be used to discover a discrete event simulation model. This method not only provides a way of data mining but also integrates process mining with the modularity, frequency, timing aspects and event data. This paper presents a mature tool applying D2FD method. This tool is implemented as an available and dedicated plug-in within the open-source process mining toolkit ProM. The simulation tool SimStudio is embedded in this plug-in and it can simulate Fuzzy–DEVS atomic and coupled model. Two case studies of real life processes, taken from Rabobank Group ICT and Dutch Employee Insurance Agency, are analyzed to evaluate this tool.

Sequential Experimentation to Efficiently Test Automated Vehicles / Zhiyuan Huang and Henry Lam (University of Michigan) and Ding Zhao (University of Michigan Transportation Research Institute)

Automated vehicles have been under heavy development in major auto and tech companies and are expected to release into market in the foreseeable future. However, the road safety of these vehicles remains a concern. One approach to evaluate their safety is via on-track experimentation, but this requires gigantic costs and time investments. This paper discusses a sequential learning approach based on kriging models to reduce the experimental runs and economize on-track experimentation. The approach relies on a heuristic simulation-based gradient descent procedure to search for the best next test scenario. We demonstrate our approach with some numerical test cases.

LOGISTICS, SCM, TRANSPORTATION / CHARLESTON E

Simheuristics for Logistics, SCM and Transportation (4)

Edward Williams (PMC)

Method to Model Actions for Discrete-event Simulations of Logistics Networks / Markus Rabe, Dominik Schmitt, and Felix Dross (Technische Universität Dortmund)

Managers of logistics networks have the complex task of continuously maintaining their network in good operating conditions under a changing environment. Thus, they need to identify promising actions to adapt and improve the logistics network. Such actions could be the relocation of stock or the adjustment of transport relations. In order to support the managers, the authors have previously proposed a decision support system (DSS) based on discrete-event simulation (DES). The DSS automatically examines possible actions and suggests the best actions found to the managers. Since a data-driven DES approach is used for this DSS, all actions can be described as changes to a database. In this paper, an approach for modeling, integrating and executing user-generated actions into the DSS is described, in order to increase its flexibility and usability. In conclusion, the authors propose to develop a domain-specific modeling language (DSML) for modeling actions for DES models.

Integrated Optimization and Simulation Models for the Locomotive Refueling System Configuration Problem / Lucas George Verschelden, Jessica L. Heier Stamm, and Todd Easton (Kansas State University)

This paper introduces the locomotive refueling system configuration problem, which arises when railroad companies aim to improve efficiency in refueling yards through new technologies or policies. Refueling speed is important to freight railroad operational efficiency; faster refueling can increase rail network capacity without the infrastructure cost associated with new terminals or

tracks. We propose a method that integrates integer programming and discrete event simulation to inform these decisions, and we demonstrate the method on data derived from industry. Specifically, the models determine the best location (denoted the “strike line”) to align trains at the refueling platform and measure the impact on refueling yard throughput associated with adopting the optimal strike lines in combination with new refueling equipment. Results using realistic parameters demonstrate a statistically significant improvement over intuitive policies.

Using Simulation to Estimate Critical Paths and Survival Functions in Aircraft Turnaround Processes / Andres San Antonio Bou (Universitat Autònoma de Barcelona), Angel A. Juan (Open University of Catalonia), Pau Fonseca (Universitat Politècnica de Catalunya), Daniel Guimarans (Amsterdam University of Applied Sciences), and Laura Calvet (Open University of Catalonia)

In the context of aircraft turnaround processes, this paper illustrates how simulation can be used not only to analyze critical activities and paths, but also to generate the associated survival functions. After motivating the relevance of the topic for both airlines and airports, the paper reviews some related work and proposes the use of Monte Carlo simulation to obtain the critical paths of the turnaround process and generate the associated survival function. This analysis is performed assuming stochastic completion times for each activity in the process. A series of numerical experiments contribute to illustrate these ideas. These experiments are based on a realistic environment considering the Boeing 737–800 aircraft, although the analysis can be easily extended to any other configuration. Different levels of passengers’ occupancy are analyzed, as well as two alternative designs for the turnaround stage.

LOGISTICS, SCM, TRANSPORTATION / SIENA

Strategic Decision Support

John Shortle (George Mason University)

Efficiency of Non-compliance Chargeback Mechanisms in Retail Supply Chains / Chun-Miin (Jimmy) Chen (Bucknell University)

In practice, suppliers fill retailers’ purchase orders to the fill–rate targets to avoid the non–compliance financial penalty, or chargeback, in the presence of service level agreement. Two chargeback mechanisms — flat–fee and linear — have been proven to effectively coordinate the supply chain in a single–period setting. However, the mechanisms’ efficiency, the incurred penalty costs necessary to coordinate the supply chain, have not been studied yet. Since retailers are often accused of treating chargeback as an additional source of revenue, this study compares the expected penalties resulted from the flat–fee or linear chargeback to shed light on the retailers’ choice of mechanisms. Using experimental scenarios consisting of various demand functions, demand variabilities, and fill–rate targets, the simulation results offer counter–evidence to the accusation.

A Simulation Study to Evaluate the Appropriate Dimensions of a New Automated Log Sorting and Storing Technology in the Wood Processing Industry / Martin Pernkopf and Manfred Gronalt (University of Natural Resources and Life Sciences, Vienna)

Most common sawmill log yards are operated by wheel loaders or log stackers. As the operational costs of this way of transportation are quite high, new technologies might be advantageous. This study assesses the feasibility and the requirements to a technology which allows to highly automate the log yard operations using automated storage components (ASCs). To find a reasonable size of the automated log yard for real–life applications data of a softwood sawmill’s log yard was analyzed and a simulation model was built. The results of the simulation study enable an educated assessment of the required dimension of the automated log storage for different scenarios.

Perspectives of a Future-Proof Primary Resource Logistics Chain / Oliver Meier, Henning Strubelt, and Sebastian Trojahn (Otto-von-Guericke-University Magdeburg)

Energy policies and energy prices have increasingly been influencing the demand for wood. For long–lasting profitability and sustainable growth of companies involved in the wood market, logistics for raw material supply is of crucial importance. This article addresses possible measures for supply chains in the wood–processing industry based on a five–year forecast horizon derived from a simulation study. It describes the design and implementation of a simulation

model to derive strategic action recommendations for raw material supply logistics for the raw material wood. Decisions concerning the size of storage locations, the number of operators in the system and the system costs can be supported by this analysis.

MASM / VERANDA E

MASM Keynote

John Fowler (Arizona State University)

Achievements and Lessons Learned from a Long-term Academic-Industrial Collaboration / Stéphane Dauzère-Pérès (Ecole des Mines de Saint-Etienne, France)

I had the opportunity to work for about 14 years on many different projects with two manufacturing sites of the French–Italian semiconductor company STMicroelectronics. Supported by European, national and industrial projects, this still active long-term academic–industrial collaboration led to many scientific and industrial achievements, spreading to other companies. Through regular exchanges, engineers, researchers, PhD and Master students were able to present their problems, their advances and generate new research projects. After some history of the collaboration, the presentation will survey some of the main research and industrial results in qualification and flexibility management, production and capacity planning, scheduling, automated transportation, dynamic sampling and time constraint management. Challenges faced and lessons learned when applying Operations Research and Industrial Engineering in practice, and in particular in semiconductor manufacturing, will be discussed. Benefits for both practitioners and researchers will be emphasized, such as the opportunity to propose and study new relevant problems and develop and apply novel approaches using actual industrial data.

STEPHANE DAUZERE-PERES is Professor at the Center of Microelectronics in Provence (CMP) of Mines Saint-Etienne in France and Adjunct Professor at BI Norwegian Business School in Norway. His research interests broadly include modeling and optimization of operations at various decision levels (from real-time to strategic) in manufacturing and logistics, with a special emphasis on semiconductor manufacturing. He has published more than 65 papers in international journals. He has coordinated multiple academic and industrial research projects. He was runner-up in 2006 of the Franz Edelman Award Competition, and won the Best Applied Paper of the Winter Simulation Conference in 2013. His email address is dauzere-peres@emse.fr.

MANUFACTURING APPLICATIONS / CHARLESTON B

New Technologies

Klaus Altendorfer (Upper Austrian University of Applied Science)

The Value of 5G Connectivity for Maintenance in Manufacturing Industry / Camilla Lundgren, Anders Skoogh, Björn Johansson, and Johan Stahre (Chalmers University of Technology) and Martin Friis (AB SKF)

Digitalization is an ongoing revolution within manufacturing industry. 5G technology is expected to play an important role in ensuring connectivity. Digitalized factories set high requirements on technical availability, and therefore also on maintenance performance. However, it is difficult to get top-level decision makers to invest in maintenance, since the effects are usually deferred and difficult to verify up front. For quantifying long term effects, Discrete Event Simulation (DES) is identified as a powerful tool. In this study, DES was combined with established maintenance concepts to provide analysis of a real-world industrial 5G pilot implementation. Maintenance concepts were used to identify relevant inputs and outputs to the simulation model. The model was tested on a use case, where 5G enables support for maintenance tasks. By applying DES and maintenance concepts on more use cases, there is a potential to quantify effects of maintenance and enable digitalized production in a larger scale.

Realistic Virtual Models for Factory Layout Planning / Daniel Näfors, Erik Lindskog, Jonatan Berglund, Liang Gong, and Björn Johansson (Chalmers University of Technology) and Johan Vallhagen (GKN Aerospace Engine Systems)

Factory layout planning is essential for manufacturing companies when designing or redesigning production systems. Layout planning usually involves 2D CAD applications, sometimes based on faulty data. Difficulties in communicating and discussing layout alternatives using such applications can lead to

critical errors, yielding inaccurate simulation models producing poor results. This paper aims to investigate and evaluate the usefulness of realistic 3D layout models in the layout planning process, addressed by an industrial study of how existing methods for visualization can be applied. This paper shows that utilizing a realistic and accurate layout model allows for fruitful discussions while several potential mistakes can be avoided. It also shows benefits in evaluating a layout and the model's accuracy in immersive virtual reality where a better perspective of the layout can be acquired. Having such evaluated layout models will enable more accurate simulation models for planned changes, based on real physical requirements.

Combining Augmented Reality and Simulation-Based Optimization for Decision Support in Manufacturing / Ingemar Karlsson, Jacob Bernedixen, Amos H.C. Ng, and Leif Pehrsson (University of Skövde)

Although the idea of using Augmented Reality and simulation within manufacturing is not a new one, the improvement of hardware enhances the emergence of new areas. For manufacturing organizations, simulation is an important tool used to analyze and understand their manufacturing systems; however, simulation models can be complex. Nonetheless, using Augmented Reality to display the simulation results and analysis can increase the understanding of the model and the modeled system. This paper introduces a decision support system, IDSS-AR, which uses simulation and Augmented Reality to show a simulation model in 3D. The decision support system uses Microsoft HoloLens, which is a head-worn hardware for Augmented Reality. A prototype of IDSS-AR has been evaluated with a simulation model depicting a real manufacturing system on which a bottleneck detection method has been applied. The bottleneck information is shown on the simulation model, increasing the possibility of realizing interactions between the bottlenecks.

SIMULATION EDUCATION / VISTAS

Education and Games

Saikou Diallo (Virginia Modeling, Analysis and Simulation Center)

Simulation-based Business Game for Teaching Methods in Logistics and Production / Alexander Hübl (Upper Austrian University of applied science) and Gudrun Fischer (Deggendorf Institute of Technology)

Uncertainty in planning tasks such as processing times, set-up times, customer required lead times, due dates, time to failure, time to repair and the complexity in terms of product variety, outsourcing, short lead times, low inventory levels, low costs and high utilization are major hurdles for planning logistics and production processes. This paper introduces a simulation-based business game for methods in planning logistics and production processes. Basic methods such as material requirement planning, Constant work in progress (Conwip), Kanban, reorder policies, dispatching rules, basic demand forecasting methods and master production schedule (MPS) are implemented in the game. Due to the generic environment additional methods can be implemented efficiently. The midterm planning concept sales and operations planning (S&OP) is implemented as well, where the gamers have to act as managers responsible for purchasing, production, sales and finance. Their target is to identify sales and production volumes for the next planning periods.

Sim4edu.com – Web-Based Simulation For Education / Gerd Wagner (Brandenburg University of Technology)

The sim4edu.com project website supports web-based simulation with open source technologies for open science and education. It provides both simulation technologies and a library of educational simulation examples. Its aim is to support both the use and the development of various kinds of simulations, including ad-hoc simulations, Cellular Automata models, NetLogo-style grid space models, discrete event simulation and agent-based simulation. Sim4edu facilitates building state-of-the-art user interfaces for web-based simulations and simulation games without requiring simulation developers to learn all the recent web technologies involved (e.g., HTML5, CSS3, SVG and WebGL). Using the power of the web, Sim4edu allows researchers and educators to publish and share their models easily.

Striving For Ubiquity of Simulation in Operations Through Educational Enhancements / Allen G. Greenwood (Poznan University of Technology)

The 50th anniversary of WSC provides a good opportunity to reflect on how

widely simulation is used in the business world to support problem solving and decision making. This paper posits that, despite the success of the WSC, simulation is not as widely used as it should be and that a major cause is a general lack of understanding of the value of simulation outside of the simulation-specialist community. However, this paper suggests that one way to increase the use of simulation is through changes in education. As part of the review and development of suggested changes, the paper examines the activities related to education at the WSC. It then offers a variety of suggestions for how the simulation education community – including academics, practitioners, and vendors – can help to address this issue.

CASE STUDIES / CHARLESTON F

Analysis

Sanjay Jain (The George Washington University)

***Improving Historical Demand Data Through Simulation* / Oroselia Sanchez and Idalia Flores (UNAM)**

Organizations collect data during different periods so that they can use them for management and business purposes. However, the data do not always come in the most suitable form for analysis, and often needs to be prepared, for which there are a variety of methods, including simulation. This paper presents a case where simulation is used as a tool to get insights into demand, based on historical data. Through simulation, we extract the most frequent demand events for two types of jobs together with the worst events. The simulation model is based on the historical data from a private oil company that operates in Mexico. In addition, we show how simulation results improve the information about Scorecard data recorded during a year of work.

***Wealth Distribution Simulation Using a System Dynamic Flow Model* / Javier Lara de Paz, Idalia Flores, and Gabriel Policroniades (UNAM)**

In a simple economic system each agent exchange its wealth in return of commodities emerging an unequal wealth and income distribution, which has been estimated through a Pareto's Distribution and by Gini's Coefficient as well. This system has been long studied using different approaches, in this work a simple model of wealth distribution is enhanced through a dynamic system simulation approach implemented in SIMIO, considering the division proposed by Statistics and Information Bureau which divides population in ten equal sized monthly income class called deciles, which are represented by ten flow tanks in a fully connected network linked with FlowConnectors from the SIMIO's flow library. Agent's wealth exchange is represented as a flow moving between tanks ruled by a specific exchanged function. Through simulation performances, using Mexico's information, a better insight and different scenarios are possible to obtain in order to support policymakers.

***Simulation Model for Studying Impact of Demographic, Temporal, and Geographic Factors on Hospital Demand* / Bozena Mielczarek and Jacek Zabawa (Wroclaw University of Science and Technology)**

This paper reports on the results of a study that aims to develop the hybrid simulation model for estimating the level and structure of the demand for healthcare services. Our research is performed for the Wrocław Region (WR), Poland. An aging chain approach is implemented in the system dynamic model to forecast the number of individuals belonging to the respective age-gender cohorts over the next 20 years. The discrete event simulation model predicts the expected volume of emergency arrivals at the WR hospitals and explores the relations between demand and demographical, temporal, and geographical aspects. The projections of long-term population evolutions are performed using parameters such as birth and death rates, life expectancy, and migration descriptors. The historical data on hospital admissions are drawn from National Health Fund regional branch registry. Our findings have important implications for the future decisions on distributions of the resources on the regional level.

CASE STUDIES / CHARLESTON D

Technique

Timothy Sprock (NIST)

Invoking ARTEMIS - The Multi-Objective Hunt for Diverse and Robust Alternative Solutions / Stephen C. Upton, Mary L. McDonald, and Susan M. Sanchez (Naval Postgraduate School) and Holly M. Zabinski (Marine Corps Combat Development Command)

The Automated Red Teaming Multiobjective Innovation Seeker (ARTEMIS) is a novel software application that implements a self-adaptive evolutionary algorithm that is designed to search for a diverse set of robust solutions in a multi-objective problem space. We present the details of our implementation and demonstrate its use on two simulation case studies that consider two objectives. The first involves potential technological enhancements for an Army infantry squad conducting an assault. The second involves unmanned aerial vehicle characteristics and employment for protecting a shipping convoy against mobile missile-launcher teams.

Modeling Fluid Simulation with Dynamic Boltzmann Machine / Kun Zhao and Takayuki Osogami (IBM Research - Tokyo)

Fluid simulation requires a significant amount of computational resources because of the complexity of solving Navier–Stokes equations. In recent work [Ladický et al., 2015], a machine learning technique has been applied to only approximate, but to also accelerate, this complex and time-consuming computation. However, the prior work has not fully taken into account the fact that fluid dynamics is time-varying and involves dynamic features. In this work, we use a time-series machine learning technique, specifically the dynamic Boltzmann machine (DyBM) [Osogami et al., 2015], to approximate fluid simulations. We also propose a learning algorithm for DyBM to better learn and generate an initial part of the time-series. The experimental results suggest the efficiency and accuracy of our proposed techniques.

Case Study in 3D Modeling of 2D Plan View CAD Data for Use in Computer Simulation / Joseph J. Wolski and Marco A. Narciso (National Institutes of Health)

Computing and computing graphics capabilities continue to improve and evolve. What was once science fiction, such as photorealistic real-time rendering now common in video games, to low cost virtual reality (VR), is now commonplace. As people experience these technologies in their personal lives, there is a greater demand and expectation that computer simulation utilized in a business or institutional setting have a similar degree of visually appealing content and user experience. These capabilities contribute to the acceptance and usefulness of these tools. This case study suggests an approach, as well as tools and techniques, utilized to automate and lessen the resources required to develop three dimensional (3D) models of a large campus environment from traditional two dimensional (2D) plan view computer aided drafting (CAD) data that can be utilized in computer simulation.

Wednesday 8:00a.m.-9:30a.m.

HISTORY OF SIMULATION / TRAILS

Computer Simulation Archive

Stephen Roberts (North Carolina State University)

Creation of the Computer Simulation Archive / Robert G. Sargent (Syracuse University) and James R. Wilson (North Carolina State University)

This paper discusses founding of the Computer Simulation Archive at North Carolina State University Libraries, obtaining the initial contributions to the archive, establishing endowments to support the archive, and forming the archive advisory committee.

The Computer Simulation Archive: Development and Current Contents / Richard E. Nance (Virginia Tech) and Gwyneth A. Thayer (North Carolina State University)

The development history of the Computer Simulation Archive is described from its inception in 1998 to the present. An overlap of visions among the creators produces an asset for the simulation community and the North Carolina State University Libraries. Collections donated over this period have produced impressive growth. Usage statistics show a steady increase in access, and the simulation endowment has nearly tripled over the past six years. The commitment of the North Carolina State University Libraries staff and the strong, consistent support of the simulation community are the key factors in this record of success.

The Importance of the Computer Simulation Archive / Greg Raschke and Susan K. Nutter (NC State University)

This paper discusses the importance, historical significance, and prestige of the Computer Simulation Archive (<https://d.lib.ncsu.edu/computer-simulation/>) at North Carolina State University Libraries, including its importance to the field of simulation and its place in the broader context of research library archival collections.

FUTURE OF SIMULATION / VERANDA A

Future of Simulation: Social and Service System Applications

Roberto San Jose (Technical University of Madrid (UPM))

Modelling of Urban Climate Impacts using Regional and Urban CFD Models. Application to Madrid (Spain) and London (UK) / Roberto San Jose, Juan Luis Perez-Camaño, and Libia Pérez (Technical University of Madrid (UPM), Computer Science School) and Rosa Maria Gonzalez-Barras (Complutense University of Madrid (UCM), Faculty of Physics)

The following paper presents the technique that can be used to produce climatic scenarios at urban scale with a spatial resolution of 10 m based on the results of the global climate models for the different RCP climate scenarios. To make the dynamic scaling process, we use the well-known mesoscale model WRF-Chem (NOAA, USA) to produce meteorological and air quality information at different scales. We start at a first level that covers all of Europe with a spatial resolution of 25 km, until it reaches the city level with a resolution of meters, which is simulated with the model MICROSYS-CFD. To show its use, 2011 was used as reference year and 2030, 2050 and 2100 as future years, with two possible scenarios RCP 4.5 and RCP 8.5. The expected impacts on wind conditions and NO₂ concentrations are shown in two European cities: Madrid and London.

A Conceptual Framework to Federate Testbeds for Cybersecurity / Lavanya Ramapantulu, Yong Meng Teo, and Ee-Chien Chang (National University of Singapore)

The transition to a “smart city” necessitates an increase in interdependencies between critical infrastructures and information technologies. Moreover, such interdependencies are across multiple domains. However, these interdependencies expose critical infrastructures to cybersecurity threats. Furthermore, the availability of domain-specific simulators everywhere motivates the need for federation of interoperable cybersecurity and cyberphysical testbeds to validate cybersecurity threat resiliency. This paper presents some key issues and challenges in accomplishing such a federation of testbeds. While there are multiple modeling and simulation approaches in specific domains, none of these works

address the challenges of federating across multiple domains such as federation between cyberphysical testbed and cybersecurity testbed to enable validation of cybersecurity resilience. We outline a reference architecture, DEFT (feDerate tEstbeds For cybersecuriTy) with design considerations that stem from the key issues highlighted.

A Spherical Monte Carlo Approach for Calculating Value-at-Risk and Expected Shortfall in Financial Risk Management / Huei-Wen Teng (National Chiao Tung University)

Accurate and efficient calculation for expected values is challenging in finance as well as various disciplines. In general, expected values can be written as high-dimensional integrals. Monte Carlo simulation is an indispensable tool for calculating them, but it is notoriously known for its slow convergence. For spherical distributions, this paper proposes a variance reduction technique and investigates its applications in finance. By using polar transformation, the expected value is written as an integral, and the innermost integral is with respect to the radius and the outermost integral is with respect to the unit sphere. The spherical Monte Carlo estimator is the average of function values of some random points generated by lattice. We consider Value-at-Risk and expected shortfall calculation under heavy-tailed distributions and demonstrate the superiority of the proposed method via numerical studies in terms of variance, computation time, and efficiency.

INTRODUCTORY TUTORIALS / RED ROCK G

Tutorials on Distributed Simulation and Modeling & Simulation for Sustainability

Martin Kunc (Warwick Business School)

An Introduction to Developing Federations with the High Level Architecture (HLA) / Alberto Falcone and Alfredo Garro (University of Calabria) and Anastasia Anagnostou and Simon J.E. Taylor (Brunel University London)

The IEEE 1516–2010 – High Level Architecture (HLA) for distributed simulation is growing in a variety of application domains due to its capabilities to enable the interoperability and reusability of distributed simulation components. However, the development of simulation models based on the HLA standard remains a challenging task that requires a considerable effort in terms of both time and cost. This paper provides an introduction tutorial on developing HLA-based simulations using the HLA Development Kit (DKF) framework. The tutorial guides developers through the necessary steps for defining and creating an HLA-based simulation, and explains how the HLA elements can be easily managed by using the DKF's services. The effectiveness of the DKF is proven by its concrete exploitation in the context of the Simulation Exploration Experience (SEE), a project led by NASA and which involves as partners several U.S. and European Institutions.

Modelling for Sustainable Development Using the Triple-Bottom Line: Methods, Challenges and the Need for Hybrid M&S / Masoud Fakhimi (University of Surrey), Navonil Mustafee (University of Exeter), and Lampros K. Stergioulas (University of Surrey)

The concept of sustainable development (SDEV) is a topic of increasing significance in management decision making. SDEV is managed based on the triple-bottom line approach which stresses the importance of achieving a balance between economic, environmental and social impacts. In the context of management decision making, this implies that operational and strategic decisions in an organization must not be limited to the fulfillment of KPIs associated with productivity alone, but should also include metrics that are associated with the environment and society. Modeling & simulation (M&S) lends itself towards evaluation of the three, often competing, metrics. There are several M&S approaches like Discrete-event and System Dynamics; which of the existing techniques is the choice for modelling SDEV? Or, is a combined hybrid approach a better solution? The tutorial explores such questions related to the methodological aspects of M&S for SDEV analysis, and discusses the challenges for modeling such complex systems.

MODELING METHODOLOGY / RED ROCK I

Parallel Simulation Applications

David Jefferson (Lawrence Livermore Nat'l Lab)

Time-Parallel Simulation of Air Traffic Networks / Young Jin Kim (Intel Corporation, Georgia Institute of Technology) and Dimitri N. Mavris and Richard M. Fujimoto (Georgia Institute of Technology)

Air traffic management is widely studied in several different fields because of its complexity and criticality to a variety of stakeholders. However, the exploding amount of air traffic in recent years has created new challenges to ensure effective management of the airspace. A fast time simulation capability is essential to effectively explore the consequences of decisions of air traffic management. A new algorithm for simulating air traffic networks using a time-parallel simulation approach is proposed that distributes time segments of the simulation scenarios across different processors. A simulation model for the National Airspace System (NAS) is described and validated. The components of the simulator are described as well as the parallel simulation algorithms. Experimental results utilizing real-world traffic data for the continental U.S. are presented demonstrating the speed ups achieved by a prototype simulator. These results illustrate that time-parallel simulation can be used to significantly accelerate certain air traffic simulations.

Some Properties of Communication Behaviors in Discrete-event Simulation Models / Patrick Crawford (University of Cincinnati), Stephan J. Eidenbenz (Los Alamos National Laboratory), Peter D. Barnes Jr. (Lawrence Livermore National Laboratory), and Philip A. Wilsey (University of Cincinnati)

This paper summarizes the profile data captured from 22 discrete-event simulation models captured from 4 different simulators. The profile data is captured by instrumenting the simulation engine and does not require any modification to the models. The profile data reported focuses on the communication properties of events exchanged between the various processes (LPs) in the model. The data suggests that some models share common behaviors and this work summarizes their general characteristics. This permits a presentation of the principle characteristics using only six of the studied models. This resulting information can be used to: (i) provide configuration data for synthetic model generation, (ii) provide direction for configuring and optimizing parallel and distributed simulation engines, and (iii) provide insights into model correctness. The focus of this specific study is to determine regularities among LP event communications that can be exploited for model partitioning and event scheduling in parallel simulation.

Concurrent Conversation Modeling and Parallel Simulation of the Naming Game in Social Networks / Kalyan Perumalla (Oak Ridge National Laboratory)

The Naming Game is an effective self-organization model to explain and understand the emergence of linguistic consensus and system dynamics in a variety of phenomena over social networks of autonomous agents. It is an effective description for the evolution of consensus despite the absence of any central coordination or specialized initialization even in large-scale networks. While the classical game is effective in description, it was defined with inherently sequential evaluation semantics over the entire network. Here, we develop a new concurrent model as a relaxation of the classical Naming Game and express the concurrent model in a discrete event style. Further, with the uncovered concurrency absent in the classical algorithm, we map the concurrent model to parallel discrete event simulation. Using a prototype implementation, we present an initial parallel simulation performance study on networks containing hundreds of thousands of individuals, with simulation time decreased from 4800 seconds to 1400 seconds.

AGENT-BASED SIMULATION / RED ROCK H

Metamodeling in Agent-Based Simulation

Andreas Tolk (MITRE Corporation)

A Meta-Algorithm for Validating Agent-Based Simulation Models to Support Decision Making / Warren Michael Volk-Makarewicz and Catherine Cleophas (RWTH Aachen University)

By explicitly modeling the decision making of heterogeneous individuals, agent-based models can compute the resulting emergent phenomena on the

micro-level. This lets planners evaluate new planning approaches for problems that depend on individual decisions. Examples include airline revenue management or traffic control. However, when decision support relies on agent-based modeling, its applicability to real-world problems depends on the model's validity. This paper introduces a novel methodological concept to decompose agent-based models for calibration and validation. This concept enables modelers to isolate agents from the evolution of the model's state variables, allowing greater choice of calibration and validation approaches. The approach first parameterizes and validates individual agents, and subsequently re-calibrates the agent-collective within the entire model.

Hypothesis-Driven Experiment Design in Computer Simulation Studies / Fabian Lorig, Daniel S. Lebherz, Jan Ole Berndt, and Ingo J. Timm (Trier University)

In simulation studies, the goal specifies the objective or purpose of the study and thus drives the entire experimentation process. Relevant experiments and respective experiment hypotheses are derived from the study's goal and the model's observed behavior provides evidence whether these hypotheses hold. Current assistance systems do not integrate research hypotheses. Thus, the researcher has to make important design decisions which limits both replicability and reproducibility of the results. In this paper, the process of simulation studies is systematized based on a formally specified hypothesis. By this means, the research hypothesis becomes the key element of the study and guides the entire process. Hypothesis-driven simulation studies allow for the automated design, execution, and evaluation of experiments based on specific research questions. This facilitates documentation and execution as well as replication of simulation studies.

Using Structural Equation-based Metamodeling for Agent-based Models / Kai G. Mertens, Iris Lorscheid, and Matthias Meyer (Hamburg University of Technology)

Trustworthy statistical modeling is an emerging challenge in agent-based modeling (ABM). However, typical characteristics of ABM such as the potential for high numbers of entities and parameters, interdependent relations between entities, several layers of effects, and emergent social phenomena challenge this process. In particular, aggregated outcomes emerging from individual agent interactions are, at least partly, difficult to measure. This might impede the statistical modeling process and thus the formulation of trustable conclusions. For this reason, we introduce structural equation modeling (SEM) as a promising statistical modeling method to analyze the behavior of ABMs. SEM allows for the estimation and evaluation of highly networked systems by explicating interactions between types of agents, measuring emergent phenomena, and identifying output patterns of simulation models. Overall, these contributions foster the credibility and trustworthiness of ABMs, and also support the communication and understanding of simulation models' behavior and their output.

CYBER-PHYSICAL SYSTEMS / CHARLESTON A

Platforms and tools

Akshay Rajhans (MathWorks)

A Distributed Simulator Platform for Rapid Industrial User Experience Prototyping / Roberto Silveira Silva Filho (GE Global research) and Alexander K. Carroll and James D. Brooks (GE Global Research)

The research and development of novel user experience concepts in well-regulated industrial domains face different challenges. Systems in these domains often require backward compatibility and integration with legacy sub-systems and protocols. They must comply with well-defined procedures and standards, and must pass through stringent evaluation processes involving actual users under realistic conditions and scenarios. As a consequence, prototyping and simulations are extensively used. During product development, the level of fidelity of a simulation prototype will directly impact the quality of end-user feedback, minimizing expensive rework of UX in later stages of a project. This paper describes the Distributed Industrial Simulation Platform (DISP), a simulation framework developed within GE that facilitates the rapid prototyping and evaluation of novel industrial UX systems. We present the DISP design and main services showing how it has been used in support of the development and simulation of two UX prototypes in the railroad transportation domain.

A Simheuristic Approach for Resource Allocation in Volunteer Computing / Javier Panadero, Laura Calvet, Joan Manuel Marquès, and Angel A. Juan (Open University of Catalonia)

The number of projects relying on volunteer computing and their complexity are growing fast. This distributed paradigm enables the gathering of idle resources (processing power and storage) to run large systems by providing scalable, practical and low cost platforms. The heterogeneity of the resources and their unreliable behavior call for advanced optimization methods. In particular, an efficient resource allocation is key for the systems' performance. This work presents a mathematical formulation and a solving approach based on a metaheuristic for the resource allocation problem. This approach is designed to deal with data-intensive applications, which must guarantee the availability of the data at all times. Moreover, a simheuristic is proposed to deal with the stochasticity of resources' quality. A set of computational experiments are performed to: (1) compare the performance of the metaheuristic and the simheuristic in a stochastic environment; and (2) quantify the effect of the stochasticity on the solutions.

Simulating Execution Time Variations in MATLAB/Simulink / Andreas Naderlinger (University of Salzburg)

Software-induced delays have a significant impact on real-time control system performance. While in extreme cases, jitter caused by execution time variations or start-time delays may compromise stability, such effects are often ignored in model-based approaches and simulations. We address this issue and discuss a Simulink block with a fundamentally new semantics that is used to encapsulate control functions as software tasks. It is particularly suited to model and observe software delays in complex control functions within software-in-the-loop (SIL) simulations. For this purpose, the controller source code is associated with platform-specific execution time information, which we assume to be available. We detail a synchronization mechanism between Simulink and such time-annotated task blocks implementing the control laws. It allows us to perform SIL simulations where controllers execute for a finite amount of simulation time and span multiple simulation steps at which they may interact with other controllers or the plant.

HYBRID SIMULATION / HILLS

Hybrid Simulation Applications

Alison Harper (University of Exeter)

Seasonal Recruiting Policies for Table Grape packing operations: A Hybrid simulation Modelling Study / Mohammed Mesabbah, Siham Rahoui, Mohamed AF Ragab, Amr Mahfouz, and Amr Arisha (Dublin Institute of Technology)

The packing process is a critical post-harvesting activity in table grape industry. Workers in packing stations are hired under seasonal contracts because of product seasonality and operations labor intensity. Seasonal workers, however, are usually characterized by inconsistent performance, high turnover and experience variation which leads to low productivity and high waste. Few mathematical models were used for evaluating fresh products packing operations, but in a deterministic nature which hinders the complexity and dynamics of the business processes. Hence, a hybrid Discrete Event Simulation (DES) and Agent-Based Modelling (ABM) are employed to evaluate a set of seasonal recruiting policies in a large grape packing station. The paper aims to investigate the impact of workers experience on packing operations efficiency. The model outcomes demonstrate the improvement in operations efficiency and total running cost (about 20% savings) that can be achieved when applying optimal recruiting policies that reduce labors variations.

Exploring Personal Data Futures Trading With Design Fiction Based Hybrid Simulation / David Bell (Brunel University London)

Personal data underpins much of our digital lives with recommenders proposing products and services that themselves result from personal usage data analysis. The ownership and use of personal data is central to much current legislation in an ever changing commercial environment. Design fictions are utilized here to explore a future where consumers (termed 'prosumers') take ownership of their personal data and offer it to a marketplace of data buyers. Personal data trading offers a disruptive opportunity to empower the end user to realize the value of their own data using new electronic trading platforms that aggregate data in response to buyer requirements. An personal data exchange-based trading platform is described where data content classification determines a selling

facade (or ‘persona’). Exploratory agent-based and system dynamics models emerge and are used to examine behavior, market dynamics and process flow within this fictional trading scenario.

Hybrid Adaptive Control for UAV Data Collection: A Simulation-based Design to Trade-off Resources Between Stability and Communication / Ezequiel Pecker Marcosig, Juan Ignacio Giribet, and Rodrigo Castro (UBA, CONICET)

We present the design of a hybrid control system for an Unmanned Aerial Vehicle (UAV) used for data collection from wireless sensors. We postulate a restrictive scenario where a low-cost processor is in charge of both flying the UAV and resolving data communication. This raises the need for safe trade-off of computing resources between stability and throughput, adapting to unpredictable environment changes. We present a strategy where a supervisory controller implements an adaptive relaxation of the sampling period of the UAV regulation controller to favor communication tasks. To guarantee stability under period switching we update the discrete-time control law with suitable gains. The resulting system comprises continuous, discrete-time and discrete-event dynamics, including event-based adaptation of the discrete-time controller. We show how the DEVS modeling and simulation framework can support a full simulation-based design, verification and validation process, featuring a seamless composition of the underlying hybrid domains.

ANALYSIS METHODOLOGY / VERANDA B

Calibration and Bias

Wei Xie (Rensselaer Polytechnic Institute)

Finite Variance Unbiased Estimation of Stochastic Differential Equations / Ankush Agarwal and Emmanuel Gobet (Ecole Polytechnique)

We develop a new unbiased estimation method for Lipschitz continuous functions of multi-dimensional stochastic differential equations with Lipschitz continuous coefficients. This method provides a finite variance estimator based on a probabilistic representation which is similar to the recent representations obtained through the parametrix method and recursive application of the automatic differentiation formula. Our approach relies on appropriate change of variables to carefully handle the singular integrands appearing in the iterated integrals of the probabilistic representation. It results in a scheme with randomized intermediate times where the number of intermediate times has a Pareto distribution.

Bayesian Sequential Calibration Using Detailed Sample Paths / Bo Wang (Rensselaer Polytechnic Institute), Qiong Zhang (Virginia Commonwealth University), and Wei Xie (Rensselaer Polytechnic Institute)

A simplified simulation model is often used to guide the decision-making for a real complex stochastic system. To faithfully assess the mean performance of the real system, it is necessary to calibrate the simulation model. Existing calibration approaches are typically built on the summary statistics of simulation outputs and ignore the dynamic information carried by the detailed sample paths. In this paper, we develop a new calibration approach incorporating the detailed output sample paths in a sequential manner. Our theoretical development and empirical study demonstrate that we can efficiently use the simulation resources and achieve better calibration accuracy by exploring the system dynamic behaviors.

Detecting Bias Due to Input Modelling in Computer Simulation / Lucy Elizabeth Morgan (Lancaster University), Barry Lee Nelson (Northwestern University), and Andrew Titman and David John Worthington (Lancaster University)

Bias due to input modelling is almost always assumed negligible and ignored. It is known that increasing the amount of real-world data available for modelling input processes causes this form of bias to decrease faster than the variance due to input uncertainty. However, this does not mean bias is irrelevant when considering the error in a simulation performance measure caused by input modelling. In this paper we present a response surface approach to bias estimation in simulation models along with a diagnostic test for identifying, with controlled power, bias due to input modelling of a size that would be concerning to a practitioner.

SIMULATION OPTIMIZATION / PAVILION

Gradient-based Simulation Optimization

Seyed Farzad Yousefian (University of Illinois Urbana-Champaign)

Data Driven Stochastic Approximation for Change Detection / Thomas Flynn (Graduate Center, City University of New York) and Olympia Hadjiliadis, Ioannis Stamos, and Felisa J. Vazquez-Abad (Hunter College, City University of New York)

Online change detection has many applications, ranging from finance and manufacturing, to security and computer vision. Designing a change detector for use in a given domain can be very time consuming, and model-based algorithms often require knowledge of the underlying stochastic model. To address these issues, in this work we explore a supervised learning approach to a change detector. We implement a gradient based procedure to find the optimal parameters for a change detector. We demonstrate the methodology on both synthetic and real world data for classifying 3D laser range image data in real-time.

A Smoothing Stochastic Quasi-Newton Method for Non-lipschitzian Stochastic Optimization Problems / Farzad Yousefian (Oklahoma State University), Angelia Nedich (Arizona State University), and Uday Shanbhag (Penn State University)

Motivated by big data applications, we consider unconstrained stochastic optimization problems. Stochastic quasi-Newton methods have proved successful in addressing such problems. However, in both convex and non-convex regimes, most existing convergence theory requires the gradient mapping of the objective function to be Lipschitz continuous, a requirement that might not hold. To address this gap, we consider problems with not necessarily Lipschitzian gradients. Employing a local smoothing technique, we develop a smoothing stochastic quasi-Newton (S-SQN) method. Our main contributions are three-fold: (i) under suitable assumptions, we show that the sequence generated by the S-SQN scheme converges to the unique optimal solution of the smoothed problem almost surely; (ii) we derive an error bound in terms of the smoothed objective function values; and (iii) to quantify the solution quality, we derive a bound that relates the iterate generated by the S-SQN method to the optimal solution of the original problem.

An Epsilon-Constraint Method for Integer-Ordered Bi-Objective Simulation Optimization / Kyle Cooper and Susan R. Hunter (Purdue University) and Kalyani Nagaraj (Oklahoma State University)

Consider the context of integer-ordered bi-objective simulation optimization, in which the feasible region is a subset of the integer lattice. We propose a retrospective approximation (RA) framework to identify a local Pareto set that involves solving a sequence of sample-path bi-objective optimization problems at increasing sample sizes. We apply the epsilon-constraint method to each sample-path bi-objective optimization problem, thus solving a sequence of constrained single-objective problems in each RA iteration. We solve this deterministic optimization problem using the SPLINE algorithm, thus exploiting gradient-based information. In early RA iterations, when sample sizes are small and standard errors are relatively large, we provide only a rough characterization of the Pareto set by making the number of epsilon-constraint problems a function of the standard error. As the RA algorithm progresses, the granularity of the characterization increases until we solve only as many epsilon-constraint problems as there are points in the local Pareto set.

HEALTHCARE APPLICATIONS / CHARLESTON C

Healthcare Services Under External Pressure

Raid Al-Alomar (Abu Dhabi University)

Operations Analysis of Hospital Ward Evacuation Using Crowd Density Model with Occupancy Area and Velocity by Patient Type / Mitsuko Yokouchi, Yuri Hasegawa, and Ryosuke Sasaki (Kobe Women's University); Rie Gaku (St. Andrew's University); Yukinori Murata and Nobuko Mizuno (Fujita Health University); and Asuka Inaba and Toshinori Tanaka (Iwasa Hospital and Maternity)

This study conducts an operational analysis of horizontal evacuation in a hospital, using a crowd density model to simulate patient evacuation. The proposed discrete event simulation model considers three types of patients assigned with specific moving speed and areas from which to evacuate; the moving speed also

varied according to the area's crowd density. We evaluated the effect of the ratio and transfer priority for each patient type on evacuation time in the ward. During night shifts, the evacuation time increased with the ratio of type 1 patients transferred by two nurses with sheets or blankets. The results showed only slight differences in evacuation times when transfer priority changed between type 1 and type 2 patients. The hospital required only one additional staff member to shorten the evacuation time during night shifts

Health Care Emergency Plan Modeling and Simulation in Case of Major Flood / Afafe Zehrouni, Vincent Augusto, Thierry Garaix, Raksmei Phan, and Xiaolan Xie (Ecole des Mines de Saint Etienne)

Health care system is one of the most critical units in case of disasters. Floods cause an increase of emergency patient flow that may overwhelm hospital resources. In this paper, we present a simulation model that evaluates health care emergency plan and assesses the resilience of the Ile-de-France region in case of a major flood. We combined in the model the health care process with a Markov chain flood model. The results can be used to elaborate an optimized strategy for evacuation and transfer operations. We provide a case study on three specialties and quantify the impact of several flood scenarios on the health care system.

Data-Driven Generic Discrete Event Simulation Model of Hospital Patient Flow Considering Surge / Carolyn R. Busby and Michael W. Carter (University of Toronto)

Many Canadian hospitals run at or near capacity, frequently experiencing congestion due to surges in demand. "Surge Protocols" that formally define when and what kind of operational steps can be taken to alleviate congestion are routinely in use. Decisions across the hospital, regarding bed capacity and allocation, staffing levels, and the surgical block schedule influence the frequency and severity of congestion, which in turn manifests in high bed occupancy, delayed admissions, crowded Emergency Department, surgical cancellations and increased use of surge protocols. A generic, data-driven, discrete event simulation is developed to help hospitals assess the impact of hospital wide decisions and surge policies on congestion. The model has been developed in cooperation with two hospitals, has been validated at a third and is continuing to be applied at additional hospitals.

LOGISTICS, SCM, TRANSPORTATION / CHARLESTON E

Flow and Inventory Optimization

Suman Niranjani (Savannah State University)

Information Blackouts in a Multi-Echelon Supply Chain Simulation / Elizabeth R. Rasnick (Georgia Southern University) and Dean C. Chatfield (Old Dominion University)

Information blackouts, sudden and short-duration failure of the information flow in a supply chain, amplify the bullwhip effect in supply chains. We use a multi-echelon, discrete-event simulation, built in Arena, to observe this phenomenon. This study uses information blackouts of inventory order history for three different lengths of time, 1, 2 and 3 periods, to help supply chain managers in decision-making during and after information blackouts. Based on the increase in bullwhip effect as the result of an information blackout, managers may decide to wait out the amplification or to use a guess and replace the missing inventory order history with the last known. The latter choice employees the common manager's heuristic of trusting the recent past to be the best predictor of the future. Our results provide supporting evidence for such managerial decisions.

Simulation Modeling of Alternative Staffing and Task Prioritization in Manual Post-Distribution Cross Docking Facilities / David Alan Cox and Manuel Rossetti (University of Arkansas)

Many supply chains have grown increasingly complex, which has led to the development of different facility types. One such facility is known as a post-distribution cross docking system (Post-C). In these facilities, bulk sorted product is received from various suppliers. Each product has its own destination, so the bulk package is broken, sorted by destination, and staged by destination. Typical processing includes: sort received goods by product type; break bulk and sort out goods by destination; move palletized goods to the staging areas of their respective destinations. This paper compares a global staffing policy (in which all workers may perform any task) to a dedicated staffing policy (in which groups of workers are assigned specific tasks). Through comparisons of the two models,

it was found the dedicated worker model's benefits from reduced change-over outweigh the lower worker utilization it experiences.

A Study of Remanufacturing System in Presence of Unreliable Supply of New Products / Suman Niranjana (Savannah State University)

We analyze a two-echelon remanufacturing system which utilizes a mix of new components as well as remanufactured old components to produce a new product. We find the optimal mix of new and old components that minimizes inventory and overall cost of the system for a fixed service levels. Additionally this system is studied assuming unreliable suppliers for new components. The systems performance is analyzed using a series of dynamic equations that are developed to describe the system under study. A simulation based optimization approach is used to study various scenarios as the demand and capacity under consideration are stochastic in nature. ARENA and Opt Quest is used for updating the equations and optimizing the system respectively. Several cases are studied under the computational study to understand the impact on the system.

MASM / VERANDA E

Scheduling Approaches I

John Fowler (Arizona State University)

Simulation-based Performance Assessment of an Implant Scheduler in Semiconductor Manufacturing / Thomas Winkler and Ralf Sprenger (GLOBALFOUNDRIES Dresden Module One LLC & Co. KG)

The processes of implanting tools in semiconductor production involve a variety of setup parameters, suggesting utilization of a scheduler for planning lot allocation in a reasonable manner. However, a scheduler is complex by design, making evaluation difficult without appropriate aids. We describe an approach using discrete event simulation software for assessing the performance and supporting the parameterization of an implant scheduler. Furthermore, rolling-horizon approaches are discussed and the scheduler performance is compared to two dispatch rules.

Robustness Analysis of an Mip for Production Areas with Time Constraints and Tool Interruptions in Semiconductor Manufacturing / Christian Maleck and Gerald Weigert (Technische Universität Dresden), Detlef Pabst (GLOBALFOUNDRIES U.S. Inc.), and Marcel Stehli (GLOBALFOUNDRIES Inc.)

This research is motivated by the need to verify and implement a schedule in a real production environment, especially in precarious production environments. This paper presents a mixed integer program (MIP) with time constraints and analysis risk parameters for tool interruptions. With the assistance of the survival analysis, a safety value will be computed and included in the MIP to downscale the available capacity. To verify the quality and robustness of the MIP, it is necessary to simulate tool interruptions and to change assumed release dates of production-bound jobs which have different stochastic distributions. To simulate these instabilities a hybrid model has been created which combines a discrete event simulation with a MIP solver. Finally, the results of the various simulations are compared.

Scheduling of Drone-based Material Transfer System in Semiconductor Manufacturing / Andy Ham (Liberty University) and DJ Kim (Micron Technology)

The idea of deploying unmanned aerial vehicles, also known as drones, for delivery in logistics operations has inspired this research. One conceivable scenario is to use a drone to transfer jobs between locations in a future semiconductor factory. Each job might be characterized by origin, destination, priority, and precedence-relationship. In particular, the precedence-relationship occurs when drones are competing for limited number of ports (similar to helicopter landing platform). The objective is to minimize the maximum completion time of all delivery jobs performed by a fleet of drones. Two exact approaches are presented: a mixed integer programming and a constraint programming, and tested for real-time perspective with problem instances up to 50-drone and 100-job.

MANUFACTURING APPLICATIONS / CHARLESTON B

Simulation Project Management

Christoph Laroque (University of Applied Sciences Zwickau)

Analysis of Communication Management in a Discrete Event Simulation Project in an High-Tech Manufacturing Company / José Arnaldo Barra Montevechi and Tábata Fernandes Pereira (Universidade Federal de Itajubá) and Amarnath Banerjee, Rachal Thomassie, and Allison Adams (Texas A&M University)

There are many projects using discrete event simulation as a decision-making tool. However, it was found in the literature that these articles are related to improving the execution of projects, not studying issues related to the management of simulation projects. From this perspective, this paper used concepts proposed by the PMBOK® to drive the management of communication between members of a simulation project and stakeholders. To achieve this goal, a real simulation case in a manufacturing company was studied. The steps of communication structure were followed and an Action Plan was elaborated and applied in this project. One of the outcomes of this effort is a communication model that was proposed for simulation projects. A questionnaire was applied in order to evaluate the proposal and results showed that simulation analysts judge communication aspects in their projects to be very important, and is strongly related to the success of the projects.

A Study of Discrete Event Simulation Project Data and Provenance Information Management in an Automotive Manufacturing Plant / Carlos Alberto Barrera Diaz and Jan Oscarsson (University of Skövde) and Simon Lidberg and Tommy Sellgren (Volvo Car Corporation)

Discrete Event Simulation (DES) project data management is a complex and important engineering activity which impacts on the organization efficiency. This efficiency could be decreased due to the lack of provenance information or to the unreliability of the existing information regarding preceding simulation projects, all of which complicates the reusability of the existing data. This study presents an analysis on the management of simulation projects and their provenance data according to the different types of scenarios usually faced in a manufacturing plant. A survey based on simulation projects from an automotive manufacturing plant was undertaken to categorize the information regarding to the studied projects, map the contained provenance data and standardize its management. This study also introduces an approach on how a structured framework based on the specific data involved in the different types of scenarios could allow an improvement on the management of DES projects.

SIMULATION EDUCATION / VISTAS

Thinking and Learning Through Modeling and Simulation

Saikou Diallo (Virginia Modeling, Analysis and Simulation Center)

Teaching Undergraduate Simulation - 4 Questions for 4 Experienced Instructors / Jeffrey Smith (Auburn University), Christos Alexopoulos (Georgia Institute of Technology), Shane G. Henderson (Cornell University), and Lee Schruben (UC Berkeley)

This paper and the corresponding panel session focus on teaching undergraduate simulation courses. The format brings together four experienced instructors to discuss four questions involving the structure and topic outlines of courses, print and software teaching materials used, and general teaching methods/philosophy. The hope is to provide some experience-based teaching information for new and soon-to-be instructors and to generate discussion with the simulation education community.

CASE STUDIES / CHARLESTON D

Healthcare 1

Fei Chen (Johnson & Johnson)

An Application of Discrete Event Simulation for Planning and Resource Allocation in a State Hospital System Servicing Both Criminal and Civil Commitments / Bradley J. Bartos M.A., Michelle Mioduszewski M.A., and Matthew Renner B.A. (University of California, Irvine; Irvine Simulation Modeling Lab) and Richard McCleary Ph.D. (University of California, Irvine; School of Social Ecology)

A discrete event simulation (DES) model with Auto-Regressive Integrated Moving Average (ARIMA) forecast inputs, sampled service times, resource capacities and scheduled resource changes was used to project inpatient populations, referral waitlists, and bed utilization for a five-site hospital system with over 6,000 patients. Based on a SAS Simulation Studio platform, the model can project arbitrary subpopulations on a three-year horizon and perform “what if” experiments with bed allocations and patient flows. This application demonstrates the utility of DES for providers with statutory obligations to serve forensic populations, while also exposing the limitations presented by missing data, non-random variations in data collection across sites, and sizable exogenous variation.

Optimization of the Emergency Department in Hospitals Using Simulation and Experimental Design: Case Study / Abdeljelil Aroua and Georges Abdul-Nour (Université de Québec à Trois Rivières)

This case study aims at evaluating the effects of different scenario policies drawn from a hospital emergency department committee of experts, using the Delphi method and a literature review, on the Emergency Department (ED) performance. The purpose is to improve patient Length of Stay (LOS). Simulation and experimental design used in order to assess the LOS sensitivities to selected parameters such as Fast Tracking, Addition of stretchers for patients under observation, Improvement of the waiting times for a consultation with a specialist, Improvement of admission waiting times, and Improvement of the treatment times for patients under observation.

A Flexible Simulation Model Aimed to Improve Inpatient Units in Health Care / Mandvi Malik and Dusan Sormaz (Ohio University)

In the past few decades, simulation in healthcare has gained immense attention from researchers because of its ability to detect problems that help in the improvement of the facility. It is important for any healthcare to know how many beds, nurses, and therapist they need in their facility to improve their service. In this research, we have created a customized object that is used to design simulation model for progressive care unit in a hospital. The objective of this research is to make a flexible simulation model that can easily be extended and re used to make simulation model for any facility. The simulation model built would help the health care personnel in determining the number of beds, therapists and nurses in their facility.

CASE STUDIES / CHARLESTON F

Manufacturing 3

Björn Johansson (Chalmers University of Technology)

Virtual Enterprise, a Management Training Tool / Sergio Valenzuela (U. de Las Américas - Chile, Evirtual - Chile)

A Virtual Enterprise is a virtual environment where participants can use management applications to improve enterprise performance. The environment emulates an organization with five positions occupied by individuals. The production operations are simulated by a model receiving the actualized data. After model runs, results are used in a balanced scorecard indicating how key performance indicators were affected with the changes made. After completing the training cycle, participants mentioned how difficult was at the beginning to be involved in order to achieve the challenge of improving profitability, but after well understood the production process, with a well communication system among them, and analyzing the key indicators, they could find the causes of low productivity and improved it. In this way, they were able to understand how strategies help to improve profitability. Considering this tool as a serious game, it is expected to reach an approach to situated learning in management field.

Searching Leverage Points to Increase Sales of a Vertically Integrated Black Tea Company / Yutaka Takahashi (School of Commerce, Senshu University) and Nobuhide Tanaka (Faculty of Economics, Gakushuin University)

A periodical purchase system, which shops deliver their goods to their customers based on contracted schedules, is one of the popular ways to keep sales stable business. Arahataen Inc., a tea company in Japan, is also providing this kind of service for consumers. They successfully won customers in their early stage. However, a recent customer number is stagnated. Then, Arahataen employed system dynamics simulation to improve their situation. This paper shows the customer number simulations for searching leverage points to improve the situ-

ation and suggests strategic intervention based on Arahataen's case.

Simulation Based Process Mapping for the Fabrication of Bridge Girders / Arash Mohsenijam, Meimanat Soleimanifar, and Ming Lu (University of Alberta)

Modern construction projects have been shifting to offsite prefabrication with hopes of enhancing performance and improving productivity. Off-site construction of structures such as heavy structural steel bridges involves the fabrication of a significant portion of the required construction components including bridge girders and assemblies in off-site fabrication facilities in a more controlled environment before delivering finished components to the construction site for erection. Unlike manufacturing, steel fabrication is labor intensive and less automated while undergoes frequent change orders and shop layout changes. These features make tracking the daily utilization of the workforce and thus labor cost and productivity difficult. To address this issue, a simplified discrete simulation approach (SDESA) is implemented to build an integrated data-driven system as an effective tool for modeling the operational details involved in the fabrication of bridge girders which supports estimating, scheduling and analyzing production.

Wednesday 10:00a.m.-11:30a.m.

HISTORY OF SIMULATION / TRAILS

Simulation History of Application Domains

Astrid Klueter (Technical University Dortmund)

A History of United States Military Simulation / Raymond R. Hill and J. O. Miller (AFIT)

The history of simulation and combat modeling associated with the military, and with military actions, is as old as the human race. Since humans began competing for resources, those involved have used simulation techniques of some form to better understand conflict and increase their chances of procuring favorable outcomes in those conflicts. This paper provides a historical perspective on the use of simulation in United States military planning, analyses, and training. This perspective starts by describing the simple table-top, thought exercises and proceeds through the development of ever more sophisticated methods to arrive at the modern United States military simulation environment, from laptop applications, through large-scale simulation models, to the advanced distributed simulation architectures currently in use.

Five Decades of Healthcare Simulation / Sally C. Brailsford (University of Southampton), Michael W. Carter (University of Toronto), and Sheldon H. Jacobson (University of Illinois)

In this paper we have not attempted to produce any kind of systematic review of simulation in healthcare to compete with the dozen (at least) excellent and comprehensive survey papers on this topic that already exist. We begin with a glance back at the early days of Wintersim, but then proceed, in line with the theme of this special track, to reflect on general developments in healthcare simulation over the years from our own personal perspectives. We include some memories and reflections by several pioneers in this area, both academics and healthcare practitioners, on both sides of the Atlantic. We also asked four current simulation modelers, who all specialize in healthcare applications but from very diverse perspectives, to reflect on their experiences. We endeavor to identify some common or recurring themes across the years, and end with a glimpse into the future.

History and Perspective of Simulation in Manufacturing / Leon F. McGinnis (Georgia Institute of Technology) and Oliver Rose (Universität der Bundeswehr München)

Manufacturing systems incorporate many semi-independent, yet strongly interacting processes, usually exhibiting some stochastic behavior. As a consequence, overall system behavior, in the long run but also in the short run, is very difficult to predict. Not surprisingly, both practitioners and academics recognized in the 1950's the potential value of discrete event simulation technology in supporting manufacturing system decision-making. This short history is one perspective on the development and evolution of discrete event simulation technology and applications, specifically focusing on manufacturing applications. This assess-

ment is based on an examination of the literature, our own experiences, and interviews with leading practitioners. History is interesting, but it's only useful if it helps us see a way forward, so we offer some opinions on the state of the research and practice of simulation in manufacturing, and the opportunities to further advance the field.

FUTURE OF SIMULATION / VERANDA A

Future of Simulation: Industrial and System Applications

Mauricio Cabrera-Rios (University of Puerto Rico at Mayaguez)

Iterative Multiple Criteria Simulation and Prototyping Optimization in Manufacturing / Esmeralda Niño-Pérez and César A. Rivera-Collazo (The Applied Optimization Group), Yaileen M. Méndez-Vázquez (Oregon State University), and Mauricio Cabrera-Ríos (The Applied Optimization Group)

In this work a multiple criteria simulation optimization method previously developed in our research group was applied to the experimental optimization of a 3D printed prototype. Both, simulation and prototyping, share the objective to provide as much information as possible about a product before its actual manufacturing. The prototype is an interlocking device that can be assembled without fastening devices or substances and that can be reassembled onto different planar assemblies. The prototype's design considered two conflicting criteria simultaneously: maximal flexural strength and minimal mass. The method mentioned previously allowed the manipulation of a set of design variables to identify configurations with the best possible balances among both criteria. This method consists of an iterative framework based on experimental design and Pareto efficiency conditions. The aim of this work is to show the potential of the method beyond its initial intended use in simulation to approach truly experimental work.

Integration Design of Supply Chain Hybrid Simulation / Wen Jun Tan and Wentong Cai (Nanyang Technological University) and Allan NengSheng Zhang (Singapore Institute of Manufacturing Technology)

To study external effects from supply chain on a firm's internal operations, it needs to construct a supply chain model. It may have sufficient data to build a detailed model of its operational processes. Since it has no control or visibility over the external entities, it is difficult to construct the rest of the supply chain model at the same level of detail. This paper proposes a hybrid model of the supply chain using integration design. It allows the supply chain to be captured at the broad view through system dynamics, and the target firm to be represented using agent-based model. The proposed model is therefore able to capture different behaviors of the same system, e.g, strategic planning of the whole supply chain, and detailed operational process of individual entities. To demonstrate the applicability of the hybrid model, we evaluate the model through a case study of disruption management policies.

INTRODUCTORY TUTORIALS / RED ROCK G

Classic DEVS Modelling and Simulation

Bhakti Stephan Onggo (Trinity College Dublin)

Classic DEVS Modelling and Simulation / Yentl Van Tendeloo (University of Antwerp) and Hans Vangheluwe (University of Antwerp, Flanders Make vzw, and McGill University)

DEVS is a popular formalism for modelling complex dynamic systems using a discrete-event abstraction. At this abstraction level, a timed sequence of pertinent "events" input to a system (or internal, in the case of timeouts) cause instantaneous changes to the state of the system. Main advantages of DEVS are its rigorous formal definition, and its support for modular composition. This tutorial introduces the Classic DEVS formalism in a bottom-up fashion, using a simple traffic light example. The syntax and operational semantics of Atomic (i.e., non-hierarchical) models are introduced first. Coupled (i.e., hierarchical) models are introduced to structure and couple Atomic models. We continue to actual applications of DEVS, for example in performance analysis of queueing systems. All examples are presented with the tool PythonPDEVS, though this introduction is equally applicable to other DEVS tools. We conclude with further reading on DEVS theory, DEVS variants, and DEVS tools.

MODELING METHODOLOGY / RED ROCK I

Networks

Stephan Eidenbenz (Los Alamos National Laboratory)

TopoGen: A Network Topology Generation Architecture with Application to Automating Simulations of Software Defined Networks / Andres Laurito and Matias Bonaventura (University of Buenos Aires), Mikel Eukeni Pozo Astigaraga (CERN), and Rodrigo Castro (University of Buenos Aires)

Simulation is an important tool to validate the performance impact of control decisions in Software Defined Networks (SDN). Yet, the manual modeling of complex topologies that may change often during a design process can be a tedious error-prone task. We present TopoGen, a general purpose architecture and tool for systematic translation and generation of network topologies. TopoGen can be used to generate network simulation models automatically by querying information available at diverse sources, notably SDN controllers. The DEVS modeling and simulation framework facilitates a systematic translation of structured knowledge about a network topology into a formal modular and hierarchical coupling of preexisting or new models of network entities (physical or logical). TopoGen can be flexibly extended with new parsers and generators to grow its scope of applicability. This allows to design arbitrary workflows of topology transformations. We tested TopoGen in a network engineering project for the ATLAS detector at CERN.

Melody: Synthesized Datasets for Evaluating Intrusion Detection Systems for the Smart Grid / Vignesh Babu, Rakesh Kumar, Hoang Hai Nguyen, David Nicol, Kartik Palani, and Elizabeth Reed (University of Illinois at Urbana Champaign)

As smart grid systems become increasingly reliant on networks of control devices, attacks on their inherent security vulnerabilities could lead to catastrophic failures. Network Intrusion Detection Systems (NIDS) detect attacks by learning traffic patterns and finding anomalies in them. However, availability of data for robust training and evaluation of NIDS is rare due to associated operational and security risks of sharing such data. Consequently, we present Melody, a scalable framework for synthesizing such datasets. Melody models both, cyber and physical components of the smart grid by integrating a simulated physical network with an emulated cyber network while using virtual time for high temporal fidelity. We present a systematic approach to generate traffic representing multi-stage attacks, where each stage is either emulated or recreated by replaying arbitrary packet traces. We evaluate the suitability of Melody's datasets for intrusion detection, by analyzing the extent to which temporal accuracy of pertinent features is maintained.

A Layered and Aggregated Queuing Network Simulator for Detection of Abnormalities / Junfei Xie (Texas A&M University-Corpus Christi), Chenyuan He and Yan Wan (University of Texas at Arlington), and Kevin Mills and Christopher Dabrowski (National Institute of Standards and Technology)

Driven by the needs to monitor, detect, and prevent catastrophic failures for complex information systems in real-time, we develop in this paper a discrete-time queuing network simulator. The dynamic model for the simulator abstracts network dynamics by taking an aggregated and layered structure. Comparative studies verify capabilities of the simulator in terms of accuracy and computational efficiency. We illustrate the model structure, flow processing mechanisms, and simulator implementation. We also illustrate the use of this simulator to detect distributed denial-of-service (DDoS) flooding attacks, based on a cross-correlation-based measure. Finally, we show that the layered structure provides new insights on the spatiotemporal spread patterns of cascading failure, by revealing spreads both horizontally within a sub-network and vertically across sub-networks.

AGENT-BASED SIMULATION / RED ROCK H**Modeling of Social Influence and Interactions**

Ashkan Negahban (Penn State University)

The Effects of Teams' Initial Characterizations of Interactions on Product Development Performance / Mohsen Jafari Songhori (Tokyo Institute of Technology), Mohammad S. Jalali (Massachusetts Institute of Technology), and Takao Terano (Tokyo Institute of Technology)

Coordinated search processes are pervasive in both organizations and product development projects. In such processes, designers with different specialties learn about their interdependent alternatives through a mutual adjustment process. In the context of a product development with several teams developing the new product's subsystems, and using reinforcement learning and agent-based simulation modeling, this study looks at the performance effects of design teams' initial mental characterizations about subsystem interactions. The focus is on two initial mental models, one in which teams over-weight their own subsystem's element interactions, and another, in which teams over-weighting interactions between subsystems. The results indicate that both initial representations have critical performance consequences for product development. Specifically, teams prioritizing their interactions of their own subsystem's elements gain short-run performance benefits as they converge to a local optimum in a short time period. Contrarily, over-weighting between-subsystem interactions leads to a tendency for teams to have long-run performance advantages.

Agent-Based and Regression Models of Social Influence / Wai Kin (Victor) Chan (Tsinghua University)

This paper studies social influence (i.e., adoption of belief) using agent-based simulation and regression models. Each agent is modeled by a linear regression model. Agents interact with neighbors by exchanging social beliefs. It is observed that if individual belief is linear in neighbors' beliefs, system-level belief and aggregated neighbors' beliefs can also be described by a linear regression model. Analysis is conducted on a simplified 2-node network to provide insight into the interactions and results of general models. Least squares estimates are developed. Explicit expressions are obtained to explain relationship between initial belief and current belief.

Neural Networks and Agent-Based Diffusion Models / Ashkan Negahban (Penn State University)

This paper introduces a new consumer decision-making model where each agent uses a neural network to evaluate word-of-mouth and predict her utility prior to adoption a new product based on her experiences in the past. The model considers the fact that consumers may not know their true preferences before experiencing the product. By using a neural network, an agent can: (1) interpret the feedback from a neighbor who has conflicting preferences with her; (2) interpret partially positive and/or negative feedback; and, (3) assign different weights to the feedback received from different neighbors. The model is implemented in an agent-based simulation model to verify that the resulting diffusion dynamics follow a typical diffusion curve. Preliminary experiments with the model also provide interesting results about the effect of the number of product attributes on the quality of an individual's utility prediction as well as proportion of satisfied adopters.

CYBER-PHYSICAL SYSTEMS / CHARLESTON A**Modeling and Simulation**

Akshay Rajhans (MathWorks)

Engineering of machine tools and manufacturing systems using cyber-physical systems / Stefan Scheifele, Oliver Riedel, and Günter Pritschow (ISW University of Stuttgart)

Today's advanced machine tool and manufacturing system engineering uses mechatronic, system-based modular kits in order to offer machines and manufacturing systems economically. The market increasingly requires not only economical production of the machine tool or manufacturing system, but also the latest technology, for example, an upgrade or exchange of mechatronic modules. This is not economically possible due to the state of the art. This

paper will present how mechatronic engineering can be developed into an engineering using cyber–physical systems (CPS). It will also present, how the engineering of machine tools and manufacturing systems will change in the future und which opportunities can be realized.

Generic Architecture for Interactive Mobile Simulation of Parallel Devs Models: a Missile Defense Application / Celine Kessler and Laurent Capocchi (University of Corsica), Bernard P. Zeigler (RTSYNC Corp.), and Jean F. Santucci (University of Corsica)

Modeling and simulation (M&S) is a discipline oriented towards engineering and research, but it tends since the very last years to be used more and more by users and developers of mobile applications through cloud computing and web services. The M&S new tools involve mobile terminals (smartphone, tablet, etc.) exchanging data quantities increasingly important from sensors with an increasing transmission speed. This paper presents a generic approach (the DEVSimPy–mob mobile application) which aims to simulate models described with the DEVS formalism (Discrete Event system Specification). DEVSimPy–mob communicates with a web REST (Representational State Transfer) server that delivers a set of web services dedicated to the simulation of DEVS models. A real case application stemming from Ballistic Missile Defense simulations is presented to show how DEVSimPy–mob can be used to launch simulations from a mobile device, interact during the simulation process and visualize results.

ANALYSIS METHODOLOGY / VERANDA B

Variance Reduction and Ranking

James R. Thompson (MITRE Corporation)

Quantile Estimation Using Conditional Monte Carlo and Latin Hypercube Sampling / Hui Dong (Amazon.com Corporate LLC) and Marvin K. Nakayama (New Jersey Institute of Technology)

Quantiles are often employed to measure risk. We combine two variance–reduction techniques, conditional Monte Carlo and Latin hypercube sampling, to estimate a quantile. Compared to either method by itself, the combination can produce a quantile estimator with substantially smaller variance. In addition to devising a point estimator for the quantile when applying the combined approaches, we also describe how to construct confidence intervals for the quantile. Numerical results demonstrate the effectiveness of the methods.

Sequential Probability Ratio Testing for Multiple-Objective Ranking and Selection / Wenyu Wang and Hong Wan (Purdue University)

In this paper, we introduce a sequential procedure for the Multi–Objective Ranking and Selection (MOR&S) problems that identifies the Pareto front with a guaranteed probability of correct selection (PCS). In particular, the proposed procedure is fully sequential using the test statistics built upon the generalized sequential probability ratio test (GSPRT). The main features of the new proposed procedure are: 1) a unified framework, the new procedure treats the multi–objective problems in the same way as the single–objective problems; 2) an indifference–zone–free formulation, the new procedure eliminates the necessity of indifference–zone parameter; 3) asymptotically optimality, the GSPRT achieves asymptotically the shortest expected sample size among all sequential tests; 4) general distribution, the procedure uses the empirical likelihood for generally distributed observation. A numerical evaluation demonstrates the efficiency of the new procedure.

SIMULATION OPTIMIZATION / PAVILION

Simulation Optimization in Risk Management

Roberto Szechtman (Naval Postgraduate School)

Computing Worst-case Expectations Given Marginals via Simulation / Jose Blanchet (Stanford University), Fei He (Columbia University), and Henry Lam (University of Michigan)

We study a direct Monte–Carlo–based approach for computing the worst–case expectation of two multidimensional random variables given a specification of their marginal distributions. This problem is motivated by several applications in risk quantification and statistics. We show that if one of the random

variables takes finitely many values, a direct Monte Carlo approach allows to evaluate such worst case expectation with $O(n^{-1/2})$ convergence rate as the number of Monte Carlo samples, n , increases to infinity.

A Sequential Elimination Approach to Value-at-risk and Conditional Value-at-risk Selection / Adam Hepworth, Michael Atkinson, and Roberto Szechtman (Naval Postgraduate School)

Conditional Value-at-Risk (CVaR) is a widely used metric of risk in portfolio analysis, interpreted as the expected loss when the loss is larger than a threshold defined by a quantile. This work is motivated by situations where the CVaR is given, and the objective is to find the portfolio with the largest or smallest quantile that meets the CVaR constraint. We define our problem within the classic stochastic multi-armed bandit (MAB) framework, and present two algorithms. One that can be used to find the portfolio with largest or smallest loss threshold that satisfies the CVaR constraint with high probability, and another that determines the portfolio with largest or smallest probability of exceeding a loss threshold implied by a CVaR constraint, also at some desired probability level.

On the Asymptotic Analysis of Quantile Sensitivity Estimation by Monte Carlo Simulation / Yijie Peng (Peking University), Michael Fu (University of Maryland), Peter Glynn (Stanford University), and Jianqiang Hu (Fudan University)

We provide a unified framework to treat the asymptotic analysis for the non-batched quantile sensitivity estimators of Fu et al. (2009), Liu and Hong (2009), and Lei et al. (2017). With only mild differences in regularity conditions and proofs, asymptotic results including strong consistency and a central limit theorem are established for all three estimators. Simulation results substantiate the theoretical analysis.

LOGISTICS, SCM, TRANSPORTATION / CHARLESTON E

Simulation of Transport Logistics Facilities and Systems

Uwe Clausen (TU Dortmund)

Simulation of the Order Process in Maritime Hinterland Transportation: The Impact of Order Release Times / Ralf Elbert, Katrin Scharf, and Daniel Reinhardt (TU Darmstadt)

The integration of information systems between the various actors organizing and executing the transport of containers to seaports is slowly progressing. Transport orders are frequently characterized by high change rates causing high manual revision effort for dispatchers. Therefore, these order changes, often received shortly before the day of departure, raise the question regarding the immediate transmission of transport orders to the subsequent actors in the transport chain. This paper analyzes the impact of different order release times, which define the timing of order transmission, on order process efficiency (processing times and costs) using a multi-method simulation approach. In a case study, four actors, two focusing on transport planning and two on operative transport execution, are considered. The simulation experiments with varying order release times and change rates reveal: A late release of orders from planning to operative actors and a reduction of order changes can significantly increase order process efficiency.

A Combined Simulation Optimization Framework to Improve Operations in Parcel Logistics / Moritz Poeting, Christin Schumacher, Jonas Rau, and Uwe Clausen (TU Dortmund University)

Operators of parcel transshipment terminals face the challenge of sorting and transferring a large number of parcels efficiently. In order to meet customers' expectations, short sorting intervals are required. In this paper we present a technical framework that combines metaheuristics with discrete-event simulation (DES) to provide robust solutions for problems at the operational level of parcel transshipment terminals. First, metaheuristics such as local search solve the problem of scheduling incoming trucks as well as allocations at the loading gates taking into account the characteristics of the internal sorting system. Next, detailed conclusions on the real system behavior are drawn by testing the solutions in DES with stochastic processing times. A framework is

used to create multiple simulation experiments for each solution. Results are investigated using the framework in order to identify the most robust solution provided by local search.

A Case Study for Simulation and Optimization Based Planning of Production and Logistics Systems / Thomas Sobottka, Felix Kamhuber, Jan Henjes, and Wilfried Sihm (Vienna University of Technology)

This paper introduces a practical approach for the comprehensive simulation-based planning and optimization of the production and logistics of a discrete goods manufacturer. Although simulation and optimization are established planning aides in production and logistics, the actual application in the field is still scarce, especially in SMEs – this is largely due to the complexity of the planning task and lack of practically applicable approaches for real life planning scenarios. This paper aims to provide a case study from the food industry, featuring a comprehensive simulation based planning. The approach utilizes an offline coupled multilevel simulation to smooth production and logistics planning via optimization, optimally configure the production system using discrete event simulation and optimize the logistics network utilizing an agent based simulation. The connected simulation and optimization modules are able to enhance the production logistics significantly, potentially providing a reference approach for similar industry applications.

MASM / VERANDA E

Scheduling Approaches II

Stephane Dauzère-Pérès (Ecole des Mines de Saint-Etienne)

Quality Based Scheduling for an Example of Semiconductor Manufactory / Dirk Doleschal and Elisa Sophie Schöttler (Technische Universität Dresden)

Quality is an important measurement within a semiconductor manufactory. Due to the fact that yield is directly affected by quality of the manufacturing process, in this paper a quality based scheduling approach will be presented which compares different methods like dispatching, MIP and CP, regarding different objectives. To test the different used methods a benchmark model of a semiconductor manufactory is build up. Here a lithography work center is used in detail where the rest of the fabrication is only build up as a delay station. With this model the repeatability for the example of a lithography step is investigated. Thereby in this investigation it is assumed, that each lithography tool has an offset which is transferred to the structure. Now the quality of a product should be best, if the offset from one layer to the next layer is minimized.

Rescheduling of Flexible Flow Shop with Sequence-Dependent Setup Times and Job Splitting / Jun Kim, Jae-Hun Lee, Seong-Lak Choi, Hyun-Jin Jung, Yoon-Bae Kim, and Hyun-Jung Kim (Sungkyunkwan University) and Byung-Hee Kim and Gu-Hwan Chung (VMS Solutions Co., Ltd.)

This paper proposes rescheduling algorithms for improving schedules obtained by dispatching rules with a commercial software program, MozArt, developed by VMS Solutions Co., Ltd.. Schedules for flexible flow shops with sequence-dependent setup times and job splitting are analyzed. The objective of the algorithms is to reduce the completion time by decreasing the number of setups and setup times. We first identify four types of problems with badly assigned job sequences and unnecessary idle times in given schedules derived from dispatching rules, and solve the problems by changing the sequence of jobs or splitting jobs. The performance of the proposed algorithms is tested with randomly generated instances based on real data from a factory in Korea.

SIMULATION EDUCATION / VISTAS

New Ways and Approaches

Saikou Diallo (Virginia Modeling, Analysis and Simulation Center)

Modeling as the Practice of Representation / Paul Fishwick (University of Texas at Dallas)

One of the characteristics of being human is to model. In our history, we began with representations of animals made from natural materials, and painted on cave walls. We also made regular marks on animal bones. While the modern accounting of these products is art (animal representations) and mathematics

(bone marks), a more comprehensive understanding points to modeling in both cases. Since the inception of modeling, we created areas of knowledge and have divided things into many groups. These groups have sub-groups to where our knowledge resembles a large house with its artificial partitions. And yet, modeling is still pervasive although it differs slightly in form among these subdivisions that we now refer to as disciplines. We claim that models are natural transformers from human experience to information; to create information for object X, create a model of X.

Storytelling and Simulation Creation / Jose J. Padilla, Christopher J. Lynch, and Hamdi Kavak (Old Dominion University) and Shawn Evett, Devon Nelson, Calvin Carson, and Joshua del Villar (Pruden Center for Industry and Technology)

When learning to create simulations, we rely on real systems to emphasize their importance on reality. However, for younger students, reliance on reality is not always engaging. Reality provides context, but students' interest quickly fades. Through the use of four case studies, we explore the idea of having students create stories in order to engage them in learning to create simulations. Applying a narrative/story context provides a mechanism for learning and maintaining student engagement. Stories can be based on original/existing games, movies, or other sources rich in narrative. Our approach includes four components: create a game/story narrative; discuss, evaluate, and expand the narrative; implement the narrative into an animated storyboard; and implement the narrative into a simulation. Lastly, we briefly discuss the utilization of sounds on both the animated storyboard and the simulation. Future work will empirically explore the effectiveness of narrative storytelling for learning simulation creation.

Proposed Unified Discrete Event Simulation Content Roadmap for M&S Curricula / James F. Leathrum, Roland R. Mielke, Andrew J. Collins, and Michel A. Audette (Old Dominion University)

This paper presents a new educational roadmap for teaching discrete event system (DES) simulation software design. This roadmap represents the hierarchical structure and inter-relationships characterizing the worldviews of DES simulation, namely, event scheduling and process interaction. The roadmap was developed from the authors' experience while teaching DES simulation to both undergraduate and graduate students, spanning several years. The roadmap's development was motivated by the need to strive for greater completeness as well as fewer inconsistencies in the material curriculum. The commonality between the worldviews is highlighted in striving for a uniform approach. The intent of this paper is to provide other educators a foundation for their own DES simulation course development. A simple example is used to illustrate the worldviews within the roadmap.

CASE STUDIES / CHARLESTON D

Healthcare 2

Guodong Shao (National Institute of Standards and Technology)

Optimization and Simulation of an Ambulance Location Problem / Idalia Flores, Esther Segura, and Alexander Vindel (UNAM)

The main Campus (Ciudad Universitaria) of the National University of Mexico (UNAM) has a population density of about 259,617 people who are attended by four ambulances and 10 technicians in medical emergencies (TME). At the present time the response time of the ambulances is, on average, from 5 to 6 min to the perimeter of the main campus. The National Fire Protection Association of USA recommends that basic life support services should arrive at the scene of an emergency within 4 minutes, while advanced life support providers should arrive within eight minutes for all TME calls. So the TME's want to find the optimum locations for the ambulances so that they can get to the patients in the shortest possible time. For this job we used simulation and integer programming to find better ambulance locations and shorten the ambulance response time in the main Campus.

Adaptive Resource Modeling To Redirect Stakeholder Perception Of Bottlenecks / Christina S. Mouradian, Shaghayegh Norouzzadeh, Nancy Riebling, and Martin Doerfler (Northwell Health)

Discrete event simulation can be utilized as a primary resource to aid critical decision-making throughout the healthcare industry. Due to the inherent complexity within this domain, effective change is highly dependent on the partnership that exists between the health system engineers and their stakeholders. An outpatient endocrinology clinic faced a problem with extended waiting times, on average 34 minutes, above the 15 minute benchmark for patients to be seen. This study uses an adaptive resource modeling approach coupled with a key partnership to identify bottlenecks and test improvement scenarios within the endocrinology clinic. Key performance indicators were traced through the simulation model to enhance system performance and optimize resource utilization. Based on the findings various improvement scenarios were proposed such as modifying resource scheduling, patient volume and resource capacity. Ultimately, the optimal improvement option presented a 30.7%, 8.5% and 46% improvement in wait time, provider efficiency and patient throughput, respectively.

Agent-based Simulation and Optimization of Hospital Utilization in a Regional Network / wei wang (Philips research), jun li (boston university), yugang jia (Philips research), and marcelo santos (philips research)

Healthcare resources allocation is inherently difficult due to the prescriptive “what-if” nature of the question being asked. One kind of data driven method is building a statistical model for resource utilization and later leverage it for resource optimization. Another kind is agent based simulation, which is based on patient choice and service queue. In this paper, we applied both methods to an imaging device resource allocation problem with a public dataset from Parana, Brazil. Our results demonstrate that starting from diametric perspectives, the two approaches give consistent and interpretable results for finding the optimal allocation. Moreover, this can serve as the corroboration for the simulation model, which is notoriously difficult to validate.

CASE STUDIES / CHARLESTON F

Transportation

Ju Yeon Lee (Korea Institute of Industrial Technology)

Denali National Park and Preserve’s Transportation System: How a Discrete Event Simulation Model Can Manage Complexity / Robin Clark (QMT Group) and William Clark and Bridget Borg (Denali National Park)

Denali National Park and Preserve’s (DNPP) Vehicle Management Plan and Environmental Impact Statement (VMP) limits road traffic to 160 vehicles permits per day. This is a tough constraint considering DNPP has 600,000 visitors per year and the park road is open only 110 days. DNPP is using analytics to study its transportation system to ensure visitor experiences are of high quality and park resources, including the historic and primitive character of the park road, remain protected under the new permit regulations. A discrete event simulation (DES) model was developed in ExtendSim to study all park traffic. The DES model arranges the complex behavior of DNPP’s road user groups into a defined event sequence using both empirical data and institutional knowledge. The DES model tests traffic volume and schedule scenarios to improve DNPP’s ability to make science-based management decisions about its transportation system with the goal of maximizing the visitor experience.

Modeling Approach for Managing the Demand in Congested Airport Networks: The Case of Mexico City Airport / Ann Wellens (DIMEI, Facultad de Ingeniería; Universidad Nacional Autónoma de México) and Miguel Mujica Mota (Aviation Academy, Amsterdam University of Applied Sciences)

We introduce a simulation approach to assess flight demand when airport congestion is observed. The model includes flight information, airline on-time performance and flight duration and turnaround time uncertainty. When airport congestion occurs at the arrival airport, an air traffic flow management initiative is triggered as a tool for alleviating the congestion problems, particularly in the most congested slots of the airport. Analysis of selected model scenarios allows to select the parameters of the initiative where airport congestion can be minimized. The model is set up for Mexico City airport, which is Mexico’s busiest airport and highly congested. This case study describes how to model

the airport network for analysing the effectiveness of specific traffic flow management initiatives in Mexico City. The flexibility of the model makes it easy to adapt it to congested airport networks in other regions of the world.

Agent-Based Simulation Modeling of a Bus Rapid Transit (BRT) Station Using Smart Card Data / SangHyung Ahn, Samuel Richard Hislop-Lynch, Jiwon Kim, and Roy Zhu (The University of Queensland)

A Bus Rapid Transit (BRT) station with multiple loading zones tends to have a longer passenger–bus interface and, thus, lead to longer passenger walking times and longer bus dwell times than ordinary bus stops. As a way to reduce bus dwell times in a BRT station, this study focuses on eliminating delays in passengers’ reaction to their desired bus by designing an improved passenger information system (PIS) that can increase passengers’ certainty about the bus stopping location. This study develops an agent–based simulation model based on observations from a BRT station in Brisbane, Australia to reflect a real BRT operations and passenger flows. The input parameters for the simulation model are calibrated with actual data including smart card records, field measurements, and video recordings. After mapping passenger moving and waiting patterns, and allocation logic of bus loading areas, various what–if analyses can be performed to design better passenger information systems.

2017 Exhibitor Directory

AnyLogic Company

Booths #26 & 27

20 N. Wacker Dr., Ste. 2044

Chicago, IL 60606

www.anylogic.com

The AnyLogic Company is a multinational team operating from the US and Europe with a global network of partners. We design, develop and market software for business applications. Our flagship product, AnyLogic, is the standard in multimethod modeling technology which equates to increased efficiency and less risk when tackling complex business challenges. This unmatched flexibility is found in all AnyLogic products allowing users to capture the complexity of virtually any system, at any level of detail, and gain a deeper insight into interdependent processes inside and around an organization. We enjoy developing best in class technologies to help our customers and partners solve the business problems they are facing. AnyLogic products are utilized world-wide in thousands of commercial organizations and academic institutions, and in over 40% of Fortune 100 Companies.

Applied Materials

Booth #29

5225 West Wiley Post Way

Salt Lake City, UT 84116

www.automod.com

Decision making in industry continues to become more complicated. Customers are more demanding as competition is fierce and costs for labor and materials continue to rise. Managers need state-of-the-art tools to help in planning, design, and operations. The AutoMod and AutoSched AP simulation products are the only simulation products on the market that provide the accuracy, scalability and performance necessary to model the most complex systems. The next evolution of simulation products are in progress ensuring that it will meet the needs of the simulation market for years to come. These advances have made AutoMod and AutoSched AP the most widely used simulation packages for material handling analyses and semiconductor modeling. The AutoMod and AutoSched AP product suite from Applied Materials has been used on thousands of projects empowering engineers and managers to make the best decisions. The power lies in its performance, scalability and accuracy in detailed modeling of large and complex manufacturing, distribution, automation and logistic operations, leaving the competition behind.

Averill M. Law & Associates, Inc.

Booth #25

4729 East Sunrise Dr., #462

Tucson, AZ 85718

www.averill-law.com

We will be featuring three products or services: (1) simulation modeling and applied statistics short courses, which have been presented more than 575 times in 20 countries; (2) the 5th edition of the book Simulation Modeling and Analysis by Averill M. Law, with 165,000 copies in print and 17,500 citations; and (3) the ExpertFit distribution-fitting software, with more than 3000 user organizations worldwide.

CSPI

Booth #13

10F, Yewon Bldg., 75-1, Yangejae-dong, Seocho-gu,

Seoul 137-889 South Korea

<http://www.cspi.co.kr>

CSPI is the world's premier solution provider devoted to dispatching, scheduling, and forecasting for high-tech industries including semiconductor, display panel, and PCB manufacturing. The solution (ezDFS) has successfully been implemented at the leading semiconductor companies located at China, Japan, Korea, and USA.

Imagine That, Inc.**Booths #24**

6830 Via Del Oro, Ste. 230

San Jose, CA 95119

www.extendsim.com

ExtendSim is not your ordinary simulation tool. It has been an advisor to production line workers as well as world leaders; a pioneer in combating hunger through the creation of higher yielding grains; a cancer fighter tracking tiny nanorobots through a bloodstream to seek out tumors; and an environmental advocate establishing a standard for the development of new energetic materials. What kind of challenge do you have for ExtendSim? If it's extra-ordinary or even if it is ordinary, ExtendSim can do it.

FlexSim Software Products, Inc.**Booth #5**

1577 North Technology Way, Ste. 2300

Orem, UT 84097

www.flexsim.com

FlexSim is excited to showcase FlexSim 2018, the latest entry in our flagship simulation modeling software, at the Winter Simulation Conference. For the past year, we've continued to innovate and develop the most capable and easy-to-use simulation solutions available. Join us for actual examples of how FlexSim has been used to solve problems in manufacturing, healthcare, and logistics, and to experience simulation through state-of-the-art virtual reality technology with immersive touch controls. We'd love to show you how FlexSim is the right fit for your simulation needs.

Frontline Systems, Inc.**Booth #30**

P.O. Box 4288

Incline Village, NV 89450

www.solver.com

Frontline Systems is democratizing analytics, enabling business analysts and managers to get results quickly — without expensive enterprise software and steep learning curves. See how easily you can solve simulation/risk analysis, optimization, forecasting and data mining problems, with just your browser, spreadsheet, or programming language — starting for free, and scaling up easily to the largest models. See Analytic Solver® for desktop Excel, AnalyticSolver.com, and our RASON® modeling language and REST API. Use our Solver and XLMiner® SDKs for C#, Java, C++, R and Python to create your own analytics applications. Find your fastest path to real analytics results.

Institute for Operations Research and the Management Sciences (INFORMS)**Booth #4**

5521 Research Park Drive, Ste. 200

Catonsville, MD 21228

www.informs.org

Visit our table to pick up the latest information on all we have to offer our members: journals, magazines, meetings, videos and podcasts, tutorials, career center, certification, continuing education, courses, Community memberships, and more. Isn't it time you become a member of INFORMS? We are now taking applications for 2018. Member benefits guides and application forms are available. INFORMS is a proud co-sponsor of the 2017 Winter Simulation Conference.

Institute of Industrial & Systems Engineers (IISE)**Booth #7**

3577 Parkway Lane, Ste. 200

Norcross, GA 30092

<http://www.iienet2.org/>

IISE is the leading provider of cutting-edge industrial engineering continuing education, and the source of productivity improvement information via the Internet, publications and live events, including an annual conference, topical conferences, technical seminars and webinars. IISE is an invaluable source of member benefits that include a magazine, professional development programs, an online career center, social networks, industry-and discipline-specific societies and divisions, chapters and affinity programs.

LLamasoft, Inc**Booth #33**

201 South Division St.

Suite 200

Ann Arbor, MI 48104

LLamasoft supply chain design software helps organizations worldwide design and improve their supply chain operations. LLamasoft solutions enable companies across a wide range of industries to model, optimize and simulate their supply chain network, leading to major improvements in cost, service, sustainability and risk mitigation. Headquartered in Ann Arbor, Michigan, LLamasoft is a leader in supply chain excellence and innovation, advancing technology focused on continuous improvement of enterprise supply chains for the world's largest organizations.

MathWorks**Booth #28**

3 Apple Hill Drive

Natick, MA 01760

www.mathworks.com

MathWorks The MATLAB and Simulink product families are fundamental applied math and computational tools adopted by more than 5000 universities and colleges. MathWorks products help prepare students for careers in industry, where the tools are widely used for data analysis, mathematical modeling, and algorithm development in collaborative research and new product development.

MOSIMTEC, LLC**Booth #23**

297 Herndon Pkwy., Ste. 301

Herndon, VA 20170

www.mosimtec.com

MOSIMTEC is a leading modeling and simulation consulting firm assisting clients in making better decisions through the application of advanced decision support tools. The MOSIMTEC team has extensive experience working with best-in-class computer simulation software. MOSIMTEC helps predict outcomes, prescribe actions, and improve operations for clients across various industries. Stop by the MOSIMTEC booth to learn more about our work, our growth, and how we can help make informed decisions.

Old Dominion University**Booth #34**

4700 Elkhorn Avenue

Modeling Sim & Visual Eng Dept

Norfolk, VA 23529

The Department of Modeling, Simulation and Visualization Engineering offers an undergraduate four-year program leading to the Bachelor of Science in Modeling and Simulation Engineering. The program is accredited by the Engineering Accreditation Commission (EAC) of ABET. Contact Rick McKenzie at rdmckenz@odu.edu.

Proplanner**Booth #3**

2321 North Loop Drive, Suite 104

Ames, IA 50010

www.proplanner.com

Proplanner is the leader of PLM-MDM (Manufacturing Data Management for the Product Lifecycle) solutions, focusing on streamlining the release of new product introductions and product updates for assembly plants. Our products import the eBOM and ECOs to integrate and author the mBOMs, process routings, tooling requirements, plant layouts, work instructions and in-plant logistics data necessary to produce complicated assemblies in many variants. Once optimized and reconciled, Proplanner can then automatically export all of this time-phased information to ERP systems such as SAP, Oracle, Mapics and JD Edwards for rapid, accurate, and optimally-engineered production release. Proplanner solutions are used by manufacturers around the world in the automotive, recreational vehicle, aerospace, agriculture and construction, military, white goods, highway vehicles, electrical equipment, medical device, and academic industries. Proplanner offers products to engineer and manage the manufacturing process and plant, as well as engineer and execute the in-plant logistics system. Assembly Planner is used to estimate activity and operation times, balance work across the assembly line considering many factors, generate and deploy shop floor instructions, and publish mBOMs and Routings to ERP. PFEP is an application used to define the placement, containerization, and replenishment of materials in stations along the assembly line; Flow Planner is used to evaluate layout and material handling resource allocation; and eKanban and eKitting electronically execute materials

replenishment. The integration of these applications provide a full solution from eBOM to production deployment. Prior to founding Proplanner in 2002, Dr. David Sly founded Cimtechnologies Corporation in 1987 around his master's thesis (FactoryFLOW). FactoryFLOW was the first AutoCAD-based factory layout and material flow analysis application. Subsequently, the company developed a suite of other plant layout applications, including FactoryCAD and FactoryPLAN. These applications are now owned by Siemens PLM, who continues to sell those products today. Dr. Sly and Proplanner have since continually focused on developing a suite of integrated plant and process engineering applications that leverage the latest technologies.

PTV GROUP

Booth #18

9755 SW Barnes Rd., Suite 290

Portland, OR 97225 USA

<http://vision-traffic.ptvgroup.com/en-us/>

PTV Group plans and optimizes everything that moves people and goods worldwide – whether it's transport routes, distribution structures, or private and public transport – all integrated, and in real-time. PTV America, Inc. is the North American subsidiary of PTV Group. We help cities, companies, and people, save both time and money. We're leaders in delivering and supporting innovative transportation and logistics solutions, and for the application of our state-of-the-art transportation software. Our main focus is to provide expertise in transportation planning, traffic operations, traffic engineering, routing, mapping and optimization for our customers.

Rockwell Automation (Arena® Simulation Software)

Booths #16 & 17

9500 Arboretum Blvd., Ste. 400

Austin, TX 78759

www.ArenaSimulation.com

Arena is the world's most widely used discrete event simulation software. Arena enables organizations to enhance operational efficiency and reliability by modeling their business processes. Companies can test and evaluate process improvement options before implementing them in actual operation. The end result is increased throughput, better use of personnel and resources and shorter processing times resulting in higher profitability. Arena is taught in more than 900 universities and is used by companies around the world, including the majority of the Fortune 100 companies.

SAGE Publishing

Booth #11

2455 Teller Rd.

Thousand Oaks, CA 91320

www.sagepublishing.com

Sara Miller McCune founded SAGE Publishing in 1965 to support the dissemination of usable knowledge and educate a global community. SAGE publishes journals, books, and library products spanning a range of subject areas. SAGE remains majority-owned by our founder, who has ensured that the company will remain permanently independent.

SAS

Booth #12

SAS Campus Dr.

Cary, NC 27513

www.sas.com

SAS Simulation Studio provides you an intuitive graphical environment for building, executing, and analyzing the results from discrete-event simulation models. You can easily model stationary and mobile resources, precisely control entity preemption, use external data in your models, and control how simulated data are created and saved. You can also integrate SAS Simulation Studio with other SAS analytics, including embedding SAS programs in simulation models and performing interactive experimental design, input analysis, and output analysis.

Simio Simulation & Scheduling Software

Booths #14 & 15

504 Beaver St.

Sewickley, PA 15143

www.simio.com

Simio Simulation and Scheduling Software is the most advanced solution on

the market. With simulation, it is the only software that is fully object oriented with process and objects being defined graphically with no programming. Unlike other scheduling software, Simio allows you to introduce risk into your production schedule with its patented Risk Based Planning and Scheduling. This dual function in Simio not only helps you improve your business performance from a facility design perspective, but also helps you maximize business results by optimizing the use of critical resources and assessing the risk associated with operational decisions.

SIMUL8 Corporation

Booth #2

225 Franklin Street

26th Floor

Boston, MA 02110

<https://www.simul8.com/>

From strategic to operational, SIMUL8's powerful simulation software can handle as much complexity as you need it to, meaning you get the results you need to make decisions fast. SIMUL8's powerful solutions have already helped global industry leaders transform their organizations and achieve higher levels of performance. From single user licenses to application development frameworks, we have the simulation product to fit your needs.

The Society for Modeling & Simulation International (SCS)

Booth #1

2598 Fortune Way, Ste. I

Vista, CA 92081

www.scs.org

SCS is the world's premier professional society devoted to modeling and simulation (M&S). Through our quality journals, JDMS and SIMULATION, and our international conferences, we serve M&S professionals from around the world. Our membership includes individuals from industry, government, and academia whose interests span all aspects of M&S.

VMS Global, Inc

Booth #6

1952 Gallows Road

Suite 110

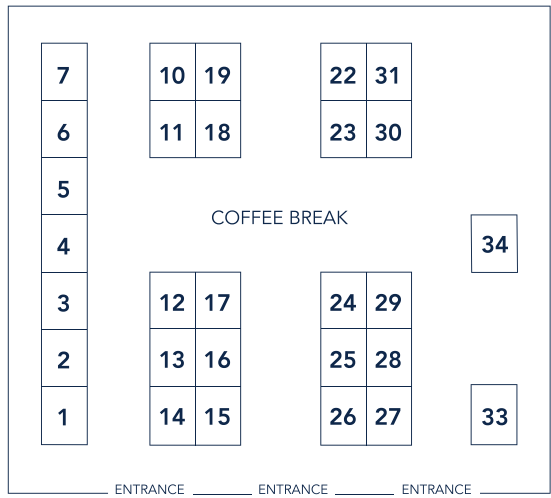
Vienna, VA 22182

<http://vms-solutions.com/>

VMS Global, Inc. has provided simulation-based planning and scheduling solutions for high-tech industries including semi-conductor, LCD/OLED panel manufacturing. As a leading SCM solution provider, VMS Global continuously improves the applications with current issues of world-renowned customers like Samsung Electronics, Samsung Display, LG Display, SK Hynix, Micron Technology. VMS Global makes the best efforts to grow with our customers through continuous technology development, and grows to be the technology-oriented venture company fulfilling CSR (corporate social responsibility)

EXHIBIT HALL

Red Rock Ballroom ABCDEF



EXHIBITORS

Booth #

AnyLogic	26 & 27
Applied Materials	29
Averill M. Law & Associates	25
CSPI	13
FlexSim Software Products, Inc.	5
Frontline Systems, Inc	30
Imagine That, Inc.	24
INFORMS	4
Institute of Industrial & Systems Engineers (IISE)	7
Llamasoft, Inc.	33
MathWorks	28
MOSIMTEC LLC	23
Old Dominion University	34
Proplanner	3
PTV Group	18
Rockwell Automation Arena Simulation Software	16 & 17
SAGE Publishing	11
SAS	12
SIMIO LLC	14 & 15
Society for Modeling and Simulation International (SCS)	1
SIMUL8 Corporation	2
VMS Global	6



WSC'17 Track Coordinators

Advanced Tutorials

Philip A. Wilsey
University of Cincinnati

Agent-Based Simulation

Ashkan Negahban
Penn State University

Levent Yilmaz
Auburn University

Analysis Methodology

James Thompson
MITRE

Architecture and Construction

Amin Hammad
Concordia University

Cheng Zhang
Xi'an Jiaotong-Liverpool University

Aviation Modeling and Analysis

Joe Hoffman
MITRE

Miguel Mujica Mota
HVA – Amsterdam University of Applied Sciences

Umut Durak
German Aerospace Center

Industrial Case Studies

Gordon Guodong Shao
NIST

Cyber-Physical Systems

José Luis Risco-Martín
Complutense University of Madrid

Akshay Rajhans
MathWorks

Environment and Sustainability Applications

Josep Casanovas
Polytechnic University of Catalonia

Pau Fonseca
Polytechnic University of Catalonia

Alessandro Pellegrini
University of Roma “La Sapienza”

Future of Simulation

Dong (Kevin) Jin
Illinois Institute of Technology

Eduardo Pérez
Texas State University

Esteban Mocskos
University of Buenos Aires

Healthcare Applications

Miguel Mujica Mota
HVA – Amsterdam University of Applied Sciences (NL)

Edward Williams
University of Michigan

History of Simulation

Robert G. Sargent
Syracuse University

Hybrid Simulation

Navonil Mustafee
Exeter University

Sally Brailsford
University of Southampton

Tillal Eldabi
Brunel University

Introductory Tutorials

Simon Taylor
Brunel University London

Anastasia Anagnostou
Brunel University London

Logistics, Supply Chain Modeling, and Transportation

Markus Rabe
TU Dortmund

David Goldsman
Georgia Institute of Technology

Manufacturing Applications

Sanjay Jain
George Washington University

Cristoph Laroque
WH Zwickau

MASM

John Fowler
Arizona State University

Lars Mönch
University of Hagen

Youin Choung
Samsung

Military Applications and Homeland Security

Ray Hill
AFIT

Subhashini Ganapathy
Wright University

Julia Phillips
Argonne National Lab

Modeling and Simulation of Intelligent, Adaptive and Autonomous Systems (MSIAAS)

Saurabh Mittal
MITRE Corporation

Jose L. Risco Martin
Complutense University of Madrid

Marco Lutzenberger
DAI-Lab, TU Berlin

Claudia Szabo
University of Adelaide

Modeling Methodology

Fernando Barros
University of Coimbra

Umut Durak
DLR

Jason Liu
Florida International University

PhD Colloquium

Emily Lada
SAS

Anastasia Anagnostou
Brunel University London

Andrea D'Ambrogio
University of Roma, Tor Vergata

Weiwei Chen
Rutgers University

Posters

Mohammad Moallemi
Embry-Riddle Aeronautical University

Shafagh Jafer
Embry-Riddle Aeronautical University

Joachim Denil
University of Antwerp

Gregory Zacharewicz
University of Bordeaux

Rodrigo Castro
University of Buenos Aires

Simulation Education

Saikou Diallo
Old Dominion University

Simulation Optimization

Scott Rosen
MITRE

Peter Salemi
MITRE

Jie Xu
George Mason University

Social and Behavioral Simulation

Adolfo López Paredes
University of Valladolid

Xiao Song
Beihang University

Vendor

Renée Thiesing
Simio

Program Committee Members & Referees

Joseph K. Agor	North Carolina State University
Darryl Ahner	Air Force Institute of Technology
Reza Akhavan	California State University East Bay
Jonathan Alt	TRADOC Analysis Center
Klaus Altendorfer	Upper Austrian University of Applied Science
Matthias Althoff	Technische Universität München
Michelle Alvarado	Texas A&M University
Vasco Amaral	Universidade Nova de Lisboa
C. Lindsay Anderson	Cornell University
Patricia Arroba	Polytechnic University of Madrid
Elie Azar	Masdar Institute
Ki-Hwan G. Bae	University of Louisville
Jacopo A. Baggio	Utah State University
Mariusz Balaban	U.S. Army
Osman Balci	Virginia Tech
Hans-Peter Barbey	Fachhochschule Bielefeld
Joseph Barjis	Delft University of Technology
Melanie Barker	Rockwell Automation
Ilaria Barletta	Chalmers University of Technology
Demet Batur	University of Nebraska-Lincoln
Emmet Beeker	The MITRE Corporation
Amir Behzadan	Texas A&M University
David Bell	Brunel University London
Tobin A. Bergen-Hill	MITRE
Jonatan Berglund	Chalmers University of Technology
Ajinkya Bhawe	Siemens PLM
Paul-Antoine Bisgambiglia	University of Corsica
Curtis Blais	MOVES Institute
Paolo Bocciarelli	University of Rome Tor Vergata
Juergen Branke	Warwick Business School
Lars Braubach	Universitat Hamburg
Peter Buchholz	TU Dortmund
Stephen J. Buckley	IBM T.J. Watson Research Center
Brad Burns	Logos Technologies
Wentong Cai	Nanyang Technological University
Christopher D. Carothers	Rensselaer Polytechnic Institute
Sean Carr	RTI
Trevor Caskey	The MITRE Corporation
Rodrigo Castro	Universidad de Buenos Aires
Nurcin Celik	University of Miami
Rohan Chabukswar	United Technologies Research Center
Supatcha Chaimatanan	ENAC
Weiwei Chen	Rutgers University
Xi Chen	Virginia Tech
Russell Cheng	University of Southampton
Ek Peng Chew	National University of Singapore
Stephen E. Chick	INSEAD
Chen-Fu Chien	National Tsing Hua University
Uwe Clausen	TU Dortmund
Andrew Collins	Old Dominion University
Ken Comer	George Mason University
Kevin Comer	The MITRE Corporation
David Cornejo	North Carolina State University
Christine Currie	University of Southampton
Gabriele D'Angelo	Università di Bologna
Brian Dangerfield	University of Bristol
Ranjita Dash	National Institute of Technology Rourkela
Stephane Dauzère-Pérès	Ecole des Mines de Saint-Etienne
Mariana De Almeida Costa	Georgia Institute of Technology
Rodrigo De la Fuente	University of Concepcion
Arjen de Leege	To70
Daniel Delahaye	Ecole Nationale de l'Aviation Civile
Jyotirmoy Deshmukh	Toyota Technical Center
Riccardo DiMatteo	Simulation Team
Anatoli Djanatliev	University of Erlangen-Nuremberg
Julie Eatock	Brunel University
David J. Eckman	Cornell University

Stephan Eidenbenz	Los Alamos National Laboratory
Tahir Ekin	Texas State University
Masoud Fakhimi	University of Surrey
Thomas Felberbauer	St. Pölten University of Applied Sciences
Paul Fishwick	University of Texas at Dallas
Idalia Flores	UNAM
Kenneth Fordyce	Arkieva
Damien Foures	Universita Corsica
Romain Franceschini	University of Corsica
Peter Frazier	Cornell University
Richard Fujimoto	Georgia Institute of Technology
Kai Furmans	KIT
Stephane Galland	UBFC, UTBM
Boon Ping Gan	D-SIMLAB Technologies Pte Ltd
Siyang Gao	City University of Hong Kong
Srinagesh Gavirneni	Cornell University
James Gentile	University of Notre Dame
Soumyadip Ghosh	IBM T.J. Watson Research Center
Jonathan M. Gilligan	Vanderbilt University
Paul Goldsman	Self-employed
Rhys Goldstein	Autodesk Research
Maheshwaran Gopalakrishnan	Chalmers University of Technology
Sabrina Gordon	University of Central Florida
Ross Gore	University of Virginia
Abhijit Gosavi	Missouri University of Science and Technology
Feng Gu	City University of New York
Canan Gunes Corlu	Boston University
Kai Gutenschwager	Ostfalia University of Applied Sciences
Andy Ham	Liberty University
Susan Hanson	The MITRE Corporation
Alison Harper	University of Exeter
Fatemeh S. Hashemi	Virginia Tech
Cathal Heavey	University of Limerick
Matt Henchey	University of Buffalo
Shane G. Henderson	Cornell University
Sunderesh S. Heragu	Oklahoma State University
Frank Herrmann	OTHochschule Regensburg
Teresa Higuera Toledano	Complutense University of Madrid
Douglas Hodson	AFIT/ENG
Andrew Hong	The MITRE Corporation
Xiaolin Hu	Department of Computer Science
Zhaolin Hu	Tongji University
Daniel Huber	Fraunhofer IAIS
Aida Huerta	UNAM
Susan R. Hunter	Purdue University
Moon Ho Hwang	Dassault Systemes
Mauro Iacono	Università degli Studi della Campania "Luigi Vanvitelli"
Ricki G. Ingalls	Texas State University
Julie Ivy	North Carolina State University
Marco Janssen	Arizona State University
Jesus A. Jimenez	Texas State University-San Marcos
Jhi-Young Joo	Lawrence Berkeley National Labs
Angel A. Juan	IN3-Open University of Catalonia
Sophia Kalakou	VTM
Adar Kalir	Intel Israel
Yasaman Kamyab Hessary	University of North Carolina at Charlotte
Angeliki Karagiannaki	Athens University
Parastu Kasaie	Johns Hopkins University
Hamdi Kavak	Old Dominion University
W. David Kelton	University of Cincinnati
Amirreza M. Khaleghi	University of Arizona
Deogratias Kibira	National Institute of Standards and Technology
Duckbong Kim	Tennessee Tech University
Yo-Han Kim	SungKyunKwan University
Seong-Hee Kim	Georgia Institute of Technology
Sujin Kim	National University of Singapore
Alexander Klaas	Miebach Consulting GmbH
Alexander Klein	AvMet Applications, Inc.
Andreas Klemmt	Infineon Technologies Dresden GmbH

Astrid Klueter	Technical University Dortmund
Markus König	Ruhr-University Bochum
Caroline C. Krejci	Iowa State University
Martin Kunc	Warwick Business School
Shalini Kurapati	TU Delft
Henry Lam	Columbia University
Hasan Latif	NCSU, NIST
Averill M. Law	Averill M. Law & Associates
Sanja Lazarova-Molnar	University of Southern Denmark
James F. Leathrum	Old Dominion University
Reda M. Lebcir	University of Hertfordshire
Loo Hay Lee	National University of Singapore
Christiane Lemieux	University of Waterloo
Peter Lendermann	D-SIMLAB Technologies
Aaron Lessin	Air Force Institute of Technology
Xueping Li	University of Tennessee
Haobin Li	National University of Singapore
Erik Lindskog	Chalmers University of Technology
Ning Liu	Illinois Institute of Technology
Xin Liu	Illinois Institute of Technology
Jennifer M. Lobo	University of Virginia
Margaret Loper	Georgia Tech Research Institute
Malcolm Low	Singapore Institute of Technology
Camilla Lundgren	Chalmers University of Technology
Lothar Maerz	STREMLER AG
Giovanni Luca Maglione	Simulation Team
Mani Manivannan	BAE Systems
Ignacio J. Martinez-Moyano	Argonne National Laboratory
Marina Massei	University of Genoa
Maria Mayorga	North Carolina State University
Martin J. Miller	Decision Analytics LLC
J.O. Miller	Air Force Institute of Technology
R. John Milne	Clarkson University
Sara Minaeian	University of Arizona
Pratik Mital	Revenue Analytics
Rahul Mittal	University of Exeter
Lars Moench	University of Hagen
Dehghani Mohammad	Northeastern University
Charles Møller	Aalborg University
Il Chul Moon	Korea Advanced Institute of Science and Technology
James R. Morrison	KAIST
John T. Murphy	Argonne National Laboratory
Chris Myers	University of Utah
Kalyani Nagaraj	Oklahoma State University
Barry L. Nelson	Northwestern University
Szu Hui Ng	National University of Singapore
Stefan Nickel	Karlsruher Institut für Technologie
David Nicol	University of Illinois at Urbana-Champaign
Libero Nigro	University of Calabria
Suman Niranjana	Savannah State University
Thierry Stephane Nouidui	Lawrence Berkeley National Laboratory
Lewis Ntamo	Texas A&M University
Halit Oğuztüzün	Middle East Technical University
Topcu Okan	METU NCC
Bhakti Stephan Onggo	Trinity College Dublin
Irfan Ovacik	INTEL
Jonathan Ozik	Argonne National Laboratory
Detlef Pabst	GlobalFoundries
Jose J. Padilla	Old Dominion University
Josué Pagán Ortiz	Universidad Complutense de Madrid
Chuljin Park	Hanyang University
Luca Parolini	BMW
Kamran Paynabar	Georgia Tech
Giulia Pedrielli	Arizona State University
Kalyan Perumalla	Oak Ridge National Laboratory
Frederic D. Petit	Argonne National Laboratory
Miquel A. Piera	Autonomous University of Barcelona
Thomas Ponsignon	Infineon Technologies AG
Nikolas Popper	TUWIEN
John Powell	University of Exeter

Sasanka Prabhala	GE Aviation
Francesco Quaglia	DIS - Sapienza Universita' di Roma
Varun Ramamohan	Indian Institute of Technology Delhi
Mohammad Raunak	Loyola University Maryland
Vasco Reis	Instituto Superior Tecnico, University of Lisbon
Judicael Ribault	University of Bordeaux
Frank Riddick	NIST
Matthew Robbins	Air Force Institute of Technology
Stewart Robinson	Loughborough University
Blaz Rodic	Faculty of Information Studies
Leonardo Rojas Nandayapa	University of Liverpool
Rodrigo Romero-Silva	Universidad Panamericana
Oliver Rose	University of the Bundeswehr Munich
Manuel D. Rossetti	University of Arkansas
Ilya Ryzhov	University of Maryland
Jorge Samayoa	Galileo University
Jibonananda Sanyal	Oak Ridge National Laboratory
Paolo Scala	Amsterdam University of Applied Sciences
Katherine Schoenfelder	The MITRE Corporation
René Séguin	Defence Research and Development Canada
Mark Seiss	Dun and Bradstreet
Michael D. Seminelli	US Military Academy
Uday Shanbhag	Penn State University
Sayed Amirhosain Sharif	Concordia University
John Shortle	George Mason University
Anders Skoogh	Chalmers University of Technology
Raymond L. Smith	North Carolina State University
Jeffrey Smith	Auburn University
Young-Jun Son	University of Arizona
Timothy Sprock	NIST
Marcel Stehli	Globalfoundries
Lampros Stergioulas	University of Surrey
Patricia Stock	REFA-Institut e.V.
Steffen Strassburger	TU Ilmenau
Anna Syberfeldt	University of Skövde
Antuela Tako	Loughborough University
Jayne Talbot	Raytheon
Jeremy J. Tejada	University of Texas - Austin
Yong Meng Teo	National University of Singapore
Angela Testi	Università degli Studi di Genova
Georgios Theodoropoulos	Durham University
Brian Thompson	The MITRE Corporation
Israel Tirkel	Ben-Gurion University
Vikram Tiwari	Vanderbilt University Medical Center
Andreas Tolk	MITRE Corporation
Juri Tolujew	Fraunhofer Institute
Maurizio Tomasella	University of Edinburgh
Daichi Toratani	Electronic Navigation Research Institute
Aineth Torres	EGADE BS
Casey Trail	Argonne National Laboratory
Mamadou Kaba Traoré	Université Clermont Auvergne
Stephen John Turner	Nanyang Technological University
Charles Turnitsa	Georgia Tech Research Institute
Tobias Uhlig	University of the Bundeswehr Munich
Adeline Uhrmacher	University of Rostock
Alfonso Urquía	UNED
Reha Uzsoy	North Carolina State University
Vahab Vahdat	Northeastern University
Antonio Vallecillo	Universidad de Malaga
DJ Van der Zee	University of Groningen
Hans Vangheluwe	McGill University and University of Antwerp
Jason Veneman	MITRE
Joe Viana	Akershus University Hospital
Gerd Wagner	Brandenburg University of Technology
Hong Wan	Purdue University
Ziteng Wang	Northern Illinois University
Honggang Wang	Rutgers University
Jens Weber	Heinz Nixdorf Institute

Gerald Weigert	TUD/IAVT
Chris Weimer	AFIT
Ann Wellens	Universidad Nacional Autónoma de México
Sigrid Wenzel	University of Kassel
Cheng-Lung Wu	UNSW Aviation
Jei-Zheng Wu	Soochow University, Taiwan
Haidong Xue	Georgia State University
Jiaqi Yan	Illinois Institute of Technology
Feng Yang	West Virginia University
Hwang Yi	Florida International University
Enver Yucesan	INSEAD
Claude Yugma	Ecole des Mines de Saint-Etienne
Zelda Zabinsky	University of Washington
Gregory Zacharewicz	University of Bordeaux - IMS
Yu Zhang	Trinity University
Si Zhang	Shanghai University
Xiaowei Zhang	Hong Kong University of Science and Technology
Yuhao Zheng	DataVisor Inc
Enlu Zhou	Georgia Institute of Technology
Chenbo Zhu	Zhejiang University of Technology

External Reviewers

Ronay Ak	NIST
Abdurrahman Alshareef	Arizona State University
Álvaro Alvares de Carvalho	
César Sobrinho	Federal Rural University of the Semi-Arid
Gaurav Ameta	NIST
Philipp Andelfinger	Karlsruhe Institute of Technology
Soren Asmussen	Aarhus University, Denmark
Ferdinand Bär	FZI
Russell R. Barton	Pennsylvania State University
Soeren Bergmann	TU Ilmenau
Bill Bernstein	NIST
Bahar Biller	General Electric
Jakey Blue	EMSE
Joseph Boi-Ukeme	Carleton University
Alex Brodsky	GMU
Michael Brundage	NIST
Bin Chen	National University of Defense Technology
Chun-Hung Chen	George Mason University
Fei Chen	Johnson & Johnson
Lih-Yuan Deng	University of Memphis
Martin Draper	IMFIA, Facultad de Ingeniería, Universidad de la República
Fabian Dunke	KIT
Weiwei Fan	University of Science and Technology of China
Philipp Fath	FZI
Peter Foytik	Old Dominion University
Jose Manuel Galan	UBU
Alfredo Garbuno Inigo	University of Liverpool
Peter Glynn	Stanford University
Sounak Gupta	UC
Arnd Hartmanns	University of Twente
Jim Henriksen	Wolverine Software
Omar Hesham	Carleton University
Jeff Hong	City University of Hong Kong
Wolfgang Hörmann	Bogazici University
Alexander Hübl	Upper Austrian University of Applied Science
Todd Huschka	Mayo Clinic
Jared Ivey	Georgia Institute of Technology
Guangxin Jiang	City University of Hong Kong
Albert Jones	NIST
Keebom Kang	Naval Postgraduate School
Bahauddin Kazi	Carleton University
Jack Kleijnen	Tilburg University
Suresh Kothari	Iowa State University

Mohan Krishnamoorthy	George Mason University
David Lechevalier	National Institute of Standards and Technology
Haengju Lee	DGIST
Y. Tina Lee	National Institute of Standards and Technology
Swee Leong	National Institute of Standards and Technology
Siyu Liao	CUNY Graduate Center
Yan Lu	NIST
Christopher Lynch	Old Dominion University
Li Ma	NIST
Matthew Maschmannm	University of Missouri
Ehsan Mehdad	Tilburg University
Melike Meterelliyoz Kuyzu	TOBB University of Economics and Technology
Bart Meyers	University of Antwerp
Cristina Montañaola	R&D / Science, Barcelona
Andreas Naderlinger	Supercomputing Center
Marvin K. Nakayama	University of Salzburg
Richard E. Nance	New Jersey Institute of Technology
Anantha Narayanan	Virginia Tech (Retired)
Luis Gustavo Nardin	National Institute of Standards and Technology
Sergio Nesmachnow	Brandenburg University of Technology
Tramy Nguyen	Universidad de la República
Alejandro Otero	University of Utah
Javier Pajares	CSC-CONICET
Juan Pavon	Universidad de Valladolid
Dennis Pegden	UCM
Ray Popovic	Simio LLC
Moritz Pötting	US Census Bureau
David Poza	TU Dortmund University
Talal Qamar	UVA - INSISOC
Elizabeth R. Rasnick	Carleton Univeristy
Paul Reynolds	Georgia Southern University
Young Ro	University of Virginia
Stephen Roberts	University of Michigan - Dearborn
Anna Carina Roemer	North Carolina State University
Cristina Ruiz-Martín	Ilmenau University of Technology
Paul Sanchez	Carleton University
Jean-François Santucci	Naval Postgraduate School
Stefan Scheifele	University of Corsica
Robert Schmalzer	ISW University of Stuttgart
Bruce Schmeiser	Technische Universität Dresden
Thomas J. Schriber	Purdue University
Lee Schruben	University of Michigan
Viktoriya Semeshenko	University of California, Berkeley
Seung-Jun Shin	IIEP-CONICET
Roberto Silva Filho	Pukyong National University
Alejandro Soba	GE
Eugene Song	CNEA
Luiz Angelo Steffemel	NIST
Gian Antonio Susto	University of Padua
James Swain	University of Alabama, Huntsville
Michael R. Taaffe	Virginia Tech
Misagh Tavanpour	Carleton University
Laurel Travis	VATECH
Carl Tropper	McGill University
Yentl Van Tendeloo	University of Antwerp
Wenjing Wang	Virginia Tech
Leandro Watanabe	University of Utah
James Wilson	North Carolina State University
Robert Wright	Texas State University
Di Wu	Georgia Institute of Technology
Rick Wysk	North Carolina State Univ.
Xu Xie	Delft University of Technology
Jun Yuan	National University of Singapore
Xudong Zhang	CUNY Graduate Center
Zhen Zhang	University of South Florida

WSC Board of Directors

The Board of Directors is responsible for the year-to-year continuity and organization of the Winter Simulation Conference. It also selects the members of the Conference Committee for each WSC. The Board consists of members from each of the eight sponsoring organizations and has four rotating officers: Chair, Vice Chair, Secretary and Liaison to each year's conference.

American Statistical Association (ASA), Technical Co-Sponsor

Fei Chen
Johnson & Johnson
fchen6@its.jnj.com

Arbeitsgemeinschaft Simulation (ASIM), Technical Co-Sponsor

Oliver Rose
Universität der Bundeswehr München
oliver.rose@unibw.de

Association for Computing Machinery/Special Interest Group on Simulation (ACM/SIGSIM)

David Nicol (Immediate Past Chair)
University of Illinois, Urbana-Champaign
nicol@iti.uiuc.edu

Andreas Tolk
MITRE Corporation
SimIS Inc.
atolk@mitre.org

Institute of Electrical and Electronics Engineers/Systems, Man, and Cybernetics Society (IEEE/SMCS), Technical Co-Sponsor

Jeffrey A. Joines
North Carolina State University
jeffjoines@ncsu.edu

Institute of Industrial Engineers (IIE)

Ann Dunkin
County of Santa Clara
ann.dunkin@isd.sccgov.org

Jeffrey S. Smith (Secretary)
Auburn University
jsmith@auburn.edu

INFORMS Simulation Society

Michael E. Kuhl
Rochester Institute of Technology
mekeie@rit.edu

Enver Yucesan
INSEAD
enver.yucesan@insead.edu

National Institute of Standards and Technology (NIST), Technical Co-Sponsor

Guodong (Gordon) Shao
NIST
gshao@nist.gov

The Society for Modeling and Simulation International (SCS)

John A. Sokolowski
VMASC, Old Dominion University
jsokolow@odu.edu

Adeline M. Uhrmacher (Chair)
University of Rostock
adeline.uhrmacher@uni-rostock.de

WSC'18 Winter Simulation Conference

December 9-12, 2018

The Swedish Exhibition & Congress Center

Gottenburg, Sweden

www.wintersim.org/2018

Preliminary Call for Papers and Presentations *Simulation For a Noble Cause*

WSC 2018 focus is on highlighting the use of simulation for noble causes!

Simulation has been found useful for a range of scientific, engineering and business applications as evident by the papers presented at Winter Simulation Conferences over the past 50 years. Simulation has been employed to help noble causes too over the recent past but such efforts have received limited attention. The 2018 conference seeks to highlight applications of simulation for noble causes in addition to continuing to report leading developments and applications in other fields. We especially invite papers describing uses of simulation in efforts analyzing and addressing issues facing humanity including, but not limited to, reducing poverty and world hunger, social causes, social problems, improving natural environment, and disaster response.

WSC 2018 KEYNOTE SPEAKER

Dr. Jean Baderschneider

CEO and Founding Board Member

Global Fund to End Modern Slavery

The Potential of Simulation for Disrupting Modern Slavery Systems

According to recent global estimates, over 25 million people are in conditions of modern slavery around the world. Modern slavery, an umbrella term which includes forced labor and forced sexual exploitation, is an economic crime of opportunity that occurs in every country in the world, generating an estimated \$150 Billion USD in illegal profits to traffickers. It is a massive system of exploitation driven by both supply of vulnerable populations and demand for cheap products and services.

The Global Fund to End Modern Slavery (GFEMS) is a bold public-private partnership with a mission to make modern slavery economically unprofitable by catalyzing and coordinating a global, coherent strategy. Dr. Baderschneider will discuss how developing this coherent strategy will require innovative approaches to collecting data and to evaluating and disrupting systems driving modern slavery. She will highlight the potential of simulation to be a game-changer in this effort.

TITANS OF SIMULATION

Russell Cheng

Emeritus Professor, University of Southampton

Peter Frazier

Associate Professor, Cornell University; Staff Data Scientist and Data Science Manager at Uber

PROGRAM

WSC 2018 features a comprehensive program ranging from introductory tutorials to state-of-the-art research and practice. Planned tracks are:

Advanced Tutorials

Analysis Methodology

Healthcare Applications

Hybrid Simulation

Agent-Based Simulation

Environment & Sustainability
Applications

Homeland Security & Emergency
Response

Industrial Case Studies

Announcement of WSC '18

Gaming	Intelligent, Adaptive & Autonomous Systems
Introductory Tutorials	Logistics, SCM, Transportation
Manufacturing Applications	Modeling and Analysis of Semiconductor Manufacturing
Modeling Methodology	Military Applications
Project Management & Construction	Networks & Communication
Simulation Education	Simulation Optimization
Simulation for a Noble Cause	Standards for Simulation
PhD Colloquium	Poster Sessions
Vendor Tutorials	

PAPER DEADLINES AND REQUIREMENTS

All contributed paper submissions will be **peer reviewed**. Accepted papers will be published in the digital version of the conference proceedings. All papers must be presented for the paper to be fully published, copyrighted and disseminated. Instructions, information, submission forms and procedures are available on the WSC website.

Each accepted paper must have a unique registration and a corresponding presentation at the conference by one of the paper's authors. Board approval is required if any single registration is attached to more than one paper.

Contributed Paper Deadlines

- **April 6, 2018:** Electronically submit contributed papers not previously published or presented. Each submission must be use the Word or LaTeX templates on the Authors Kit. The page size in the proceedings is 8.5 by 11 inches (21.6 cm by 27.9 cm). Papers should be at most 12 pages (including an abstract of not more than 150 words), except for introductory tutorials, advanced tutorials, and panel sessions, for which the limit is 15 pages. Submission implies that an author will attend WSC 2018 and present the paper, and all clearance required for publication of the paper will be obtained by July 15, 2018. Use of the authors' templates in one of the following formats is required: Microsoft Word or LaTeX. Submissions must be made through the WSC website.
- **June 1, 2018:** Notification of acceptance
- **June 30, 2018:** Authors electronically submit corrected papers to the Proceedings Editor.
- **July 15, 2018:** Authors electronically provide a final manuscript meeting all technical and format requirements to the Proceedings Editor.

Poster Session or Ph.D. Colloquium (One or the other, submission to both Poster Session and the PhD Colloquium is not allowed for 2018)

- **August 18, 2018:** electronically submit 2-page extended abstracts for presentations in the Poster Session and Ph.D. Student Colloquium. Extended abstracts are used for designing the tracks, but are not peer reviewed parts of the proceedings.
- **September 14, 2018:** Notification of acceptance to authors (including details about submitting slides, and formats of the posters).
- **October 5, 2018:** Final extended abstracts due.
- **October 26, 2018:** Slides for the presentation due (see guidelines in the track information)
- **December 9, 2018:** Bring your poster to WSC 2018. The Poster Madness Session and Ph.D. Colloquium both run on Sunday December 9, so participation in both is not possible.

Case Study Deadlines

- **August 18, 2018:** electronically submit 2-page extended abstracts for presentations. Extended abstracts are used for designing the tracks, but are not peer reviewed parts of the published proceedings.
- **September 14, 2018:** Notification of acceptance to authors (including details about submitting slides, and formats of the posters).
- **October 5, 2018:** Final extended abstracts due.

WSC 2018 is sponsored by ACM/SIGSIM, ASA (Technical Co-Sponsor), ASIM (Technical Co-Sponsor), IEEE/SMC (Technical Co-Sponsor), IIE, INFORMS-SIM, NIST (Technical Co-Sponsor) and SCS.

WSC FOUNDATION

The purpose of the WSC Foundation (WSCF) is to develop and manage a Fund to help ensure the continuance and high quality of the Winter Simulation Conference (WSC). Management of the Fund allows for (a) providing loans or grants from the Fund to the WSC Board of Directors when the WSC Board makes such requests and the WSCF deems it prudent and wise to do so; (b) allocating assets of the Fund to balance return, risk and liquidity; and (c) accepting donations to the Fund and raising money for the Fund as and when it is deemed appropriate. The WSCF operates independently of the WSC Board of Directors, and is also independent of the annual WSC Committees. The WSCF operates under the parent organization INFORMS.

Everyone in the international simulation community is deeply indebted to the patrons listed below for their unwavering support. In the case of multiple donations from the same individual, corporation or organization, the amounts of the donations are cumulative in terms of determining the category of donation.

For more information on the WSC Foundation, please visit:

<http://connect.informs.org/wscfoundation>

Sustaining Patrons (\$500 or More)

Anonymous Donations "In Honor of James Reed Wilson III" (2)

Anonymous Donors (2)

Brad Armstrong (CertainTeed)

Russell Barton (Penn State)

Osman Balci (Virginia Tech)

William E. Biles (University of Louisville)

Justin Boesel (The MITRE Corporation)

Felix Breitenecker (ARGESIM-Vienna University of Technology)

John M. Charnes (The University of Kansas)

Ann Dunkin (Hewlett-Packard Company)

David M. Ferrin (Business Prototyping, Inc.)

John W. Fowler (Arizona State University)

Michael C. Fu (University of Maryland)

David Goldsman (Georgia Tech)

Peter and Laura Haas (IBM Corporation)

Raymond Hill (and the entire Dept. of Biomedical, Industrial & Human Factors Engineering, Wright State University)

INFORMS-College on Simulation

Ricki G. Ingalls (Oklahoma State University)

Keebom Kang (Naval Postgraduate School)

W. David Kelton (University of Cincinnati)

Vlad Lewis and Natasha Smith, "In Memory of Peter A. W. Lewis"

Martin Miller (Business Prototyping, Inc.)

Douglas and Deanna Morrice (The University of Texas at Austin)

Richard E. Nance (Virginia Tech)

Barry L. Nelson (Northwestern University)

C. Dennis Pegden (Rockwell Software)

Charles H. Reilly (University of Central Florida)

Stephen D. Roberts (North Carolina State University)

Paul J. Sánchez (Naval Postgraduate School)

Susan M. Sanchez (Naval Postgraduate School)

Bruce W. Schmeiser (Purdue University)

Thomas J. Schriber (University of Michigan)

Donna and Lee Schruben (University of California, Berkeley)

Herb Schwetman (Mesquite Software, Inc.)

Leyuan Shi (University of Wisconsin-Madison)

Jane L. Snowdon (IBM T. J. Watson Research Center)

Jeffrey D. Tew (General Motors Research and Development Center)

Michael R. Taaffe (Virginia Tech)

K. Preston White (University of Virginia)

Frederick P. Wieland (The MITRE Corporation)

James R. Wilson (North Carolina State University)

Enver Yücesan (INSEAD)

Gold Patrons (\$250 - \$499)

Simaan AbouRizk (University of Alberta)
 Anonymous Donor
 Athanassios N. Avramidis (University of Montreal)
 Martha A. Centeno (Florida International University)
 Russell C.H. Cheng (University of Southampton)
 Randall Gibson (Automation Associates, Inc.)
 Paul Glasserman (Columbia University)
 Donald Gross (George Mason University)
 Michael E. Kuhl (Rochester Institute of Technology)
 Mani Mannivannan (Vector SCM)
 Susumu Morito (Waseda University)
 Kenneth Musselman (MAPICS, Inc.)
 Ray J. Paul (and the entire Dept. of Information Systems & Computing, Brunel University)
 Michael Pidd (Lancaster University)
 Ralph Rogers (East Carolina University)
 Robert G. Sargent (Syracuse University)
 James J. Swain (The University of Alabama in Huntsville)
 Brian Unger (University of Calgary)

Silver Patrons (\$125 - \$249)

Christos Alexopoulos (Georgia Tech)
 Sigrún Andradóttir (Georgia Tech)
 Anonymous Donor
 Farhad Azadivar (University of Massachusetts Dartmouth)
 Diane P. Bischak (University of Calgary)
 John S. Carson, II (Brooks Automation, Inc.)
 Chun-Hung Chen (George Mason University)
 E. Jack Chen (BASF Corporation)
 Paul A. Fishwick (University of Florida)
 Seong-Hee Kim (Georgia Tech)
 Averill M. Law (Averill Law & Associates)
 Pierre L'Ecuyer (University of Montreal)
 Gerald T. Mackulak (Arizona State University)
 Daniel J. Muller (Brooks Automation, Inc.)
 Julian Reitman (Retired)
 Manuel D. Rossetti (University of Arkansas)
 Robert E. Shannon (Texas A&M University)
 J. D. Selby-Lucas (East Carolina University)
 Jeffrey S. Smith (Auburn University)
 Pandu Tadikamalla (University of Pittsburgh)
 Peter D. Welch (Walpole Software)

Patrons (Any Amount)

Anonymous Donors (2)
 Jerry Banks (Independent Consultant)
 Maged M. Dessouky (University of Southern California)
 Gerald W. Evans (University of Louisville)
 Philip Heidelberg (IBM T.J. Watson Research Center)
 Joseph C. Hagan (Forward Vision Services)
 Lawrence M. Leemis (The College of William & Mary)
 D. J. Medeiros (The Pennsylvania State University)
 David M. Nicol (University of Illinois)
 Acácio M.O. Porta Nova (and the entire Dept. of Engineering & Mgt., Instituto Superior Técnico, Lisbon)
 Stephen M. Robinson (University of Wisconsin-Madison)
 Perwez Shahabuddin (Columbia University)
 Charles R. Standridge (Grand Valley State University)
 Thomas R. Willemain (Rensselaer Polytechnic Institute)
 David H. Withers (Retired)

CD-ROM and USB Key Instructions

Getting Started

The contents of this product are designed to be viewed directly from the media (CD or USB Key) using a web browser. To access content, double click the main HTML file named **2017 WSC Content.htm** and it will open in your web browser.]

Software Requirements

Windows®: Windows 98 or newer, Internet Explorer with Active Content enabled or Netscape, Mozilla, Firefox, Opera, or any browser with Java and JavaScript (AOL browser not supported), Java 1.4 or newer (if using non-IE browser), Adobe Flash® Player for multimedia content

Macintosh®: Mac OS X 10.3.4 or newer (older versions will not be able to search), Safari 1.3.1 with Java and JavaScript enabled, Java 1.4.1 update 2 or newer, Adobe Flash® Player for multimedia content

UNIX®/Linux®: Netscape, Mozilla, Firefox, Opera, or any browser able to use Java and JavaScript (Konqueror is not supported), Java 1.4 or newer, Adobe Flash® Player for multimedia content

Adobe® Reader® 5.0 or newer for viewing PDF content (version 7.0.5 or newer recommended).

Additional software may be needed to view some materials included on this product.

Need Help?

Refer to the “readme.htm” document located on this disc for general product support, downloading and installing Adobe Reader, and copying this product to your hard disk or network.

A complete help file is accessible from the main menu of this product (internet connection optional). Omnipress technical support is available by e-mail at digital@omnipress.com. Limited support for UNIX and Linux systems. This product is not supported if hosted on a web server.

This product was produced by Omnipress – leaders in conference & educational publications.

www.omnipress.com

No part of the Omni EZ-Setup™ software and product “Help” files may be reproduced or used without the written permission of Omnipress. ©2013 Omnipress. All rights reserved. All other trademarks are property of their respective owners.

NOTES

NOTES

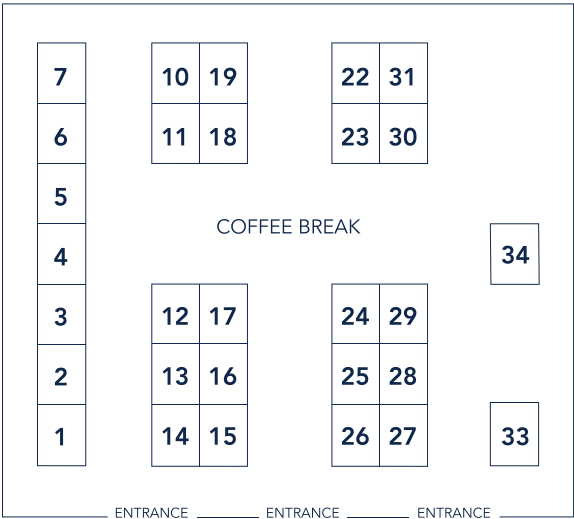
NOTES

NOTES

NOTES

EXHIBIT HALL

Red Rock Ballroom ABCDEF



EXHIBITORS

Booth

AnyLogic	26 & 27
Applied Materials	29
Averill M. Law & Associates	25
CSPI	13
FlexSim Software Products, Inc.	5
Frontline Systems, Inc	30
Imagine That, Inc.	24
INFORMS	4
Institute of Industrial & Systems Engineers (IISE)	7
Llamasoft, Inc.	33
MathWorks	28
MOSIMTEC LLC	23
Old Dominion University	34
Proplanner	3
PTV Group	18
Rockwell Automation Arena Simulation Software	16 & 17
SAGE Publishing	11
SAS	12
SIMIO LLC	14 & 15
Society for Modeling and Simulation International (SCS)	1
SIMUL8 Corporation	2
VMS Global	6

FUTURE WINTER SIMULATION CONFERENCES

December 9–12, 2018

The Swedish Exhibition & Congress Centre
Gothenburg, Sweden
Chair: Bjørn Johansson

December 8–11, 2019

Gaylord National Resort & Convention Center
National Harbor, Maryland
Chair: Young-Jun Son

December 13–16, 2020

Orlando World Center Marriott
Orlando, Florida
Chair: Renée Thiesing

December 12–15, 2021

JW Marriott Desert Ridge
Phoenix, Arizona
Chair: Margaret Loper

SPONSORING SOCIETIES WSC 2017

American Statistical Association (ASA)
Technical Co-Sponsor

Arbeitsgemeinschaft Simulation (ASIM)
Technical Co-Sponsor

Association for Computing Machinery:
Special Interest Group on Simulation (ACM/SIGSIM)

Institute of Electrical and Electronics Engineers:
Systems, Man, and Cybernetics Society (IEEE/SMC)
Technical Co-Sponsor

Institute for Operations Research and the
Management Sciences (INFORMS-SIM)

Institute of Industrial Engineers (IIE)

National Institute of Standards and Technology (NIST)
Technical Co-Sponsor

The Society for Modeling and
Simulation International (SCS)