

# 1<sup>st</sup> IFAC Workshop LPVS2015 on Linear Parameter Varying Systems

FINAL PROGRAM AND BOOK OF ABSTRACTS



**Grenoble, France  
October, 7-9, 2015**





# Greetings and thanks

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Bienvenue à Grenoble! On behalf of the National Organizing Committee and of the International Program Committee of the 1st IFAC Workshop on Linear Parameter Varying Systems, we are delighted to welcome you in Grenoble, the capital of the French Alps.

Linear Parameter Varying systems have state space representations that depend on time-varying parameters. This class of systems allows representing several types of systems such as non-linear systems, switching systems, multi-models, etc. This workshop aims at presenting some results in the field of LPV systems and applications, more and more studied in the control community. The aim is to bring together experts working in LPV systems to discuss new trends, exchange new ideas, establish fruitful contacts, and promote interactions among the various fields of interest.

The workshop topics cover the control area for LPV systems : modelling, analysis, observation and control. Two plenary sessions, “Robust Analysis and Synthesis for Linear Parameter Varying Systems” by Peter Seiler and “On the Flexibility of the Gain-Scheduling Paradigm” by Carsten Scherer, and 7 technical sessions have been scheduled : 4 on methodological aspects (Control Methods 1, Control Methods 2, FDI/FTC and Identification), and 3 on applicative aspects (Aerospace, Automotive and Applications).

This workshop is mainly sponsored by the TC 2.2 Linear Control Systems, and co-sponsored by TC 1.1. Modelling, Identification and Signal Processing, TC 2.5. Robust Control, TC 6.4. Fault Detection, Supervision & Safety of Technical Processes-SAFEPROCESS, and TC 7.3. Aerospace.

Organizing such a first event is always a challenge that could not be achieved without the help of some key persons. We would like to thank specifically the IPC co-Chairs Luc Dugard and Nicos Karcanias who largely contributed to the reviewing process and paper selection for this workshop. Thanks also to the members of the IPC who have allowed a high paper selection.

We also would like to thank the secretariat of GIPSA-lab who has been involved in the NOC and who will make unforgettable this conference for all the participants. We then hope you will enjoy the social events (the Wine & Cheese welcome reception and the conference dinner) in the center of Grenoble, as well as the Grenoble surroundings.

Finally thanks to all the authors and chairs, IPC members and volunteers who will make this 1st IFAC Workshop LPVS in Grenoble a great success and, hopefully, the beginning of a long story.

We hope that you will enjoy the technical program.

Bonne conférence !

*Olivier Sename*, General and NOC Chair

*Marco Lovera*, IPC chair

*Mirko Fiacchini*, Publication Chair

# International Program Committee

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<b>Co-Chair</b>	Luc Dugard	CNRS, Grenoble, FR
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# General informations

## Conference location

The IFAC LPVS2015 workshop will take place in the Saint Martin d'Hères Campus of Grenoble, at :

*Maison Jean Kutzmann (MJK)  
100 rue de la Chimie, Domaine Universitaire  
38400 Saint Martin d'Hères*

(see infos and maps on <https://mi2s.imag.fr/how-to-find-us>)



## Coming to GRENOBLE CAMPUS

### By Tram

- From Grenoble Center and Grenoble Station (Map Tram lines) : Line B "Gières Plaine des Sports". Stop Station : "Gabriel Fauré" or "Bibliothèques universitaires".
- From Gières Station : Line B "Grenoble International City". Stop Station : "Gabriel Fauré" or "Bibliothèques universitaires".

### By Car

- Arriving from Highway A41 from Chambéry : Southern Bypass (N87) Exit No 1 (Domaine Universitaire)
- Arriving from Highway A48 from Lyon : follow Chambéry then Exit No 1 (Domaine Universitaire)
- Arriving by Highway A480 from Sisteron : follow Chambéry, then Exit No. 1 (Domaine Universitaire)

# Sponsors

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- GIPSA-lab, Grenoble



- Centre National de la Recherche Scientifique, CNRS



- Grenoble Institute of Technology, INP



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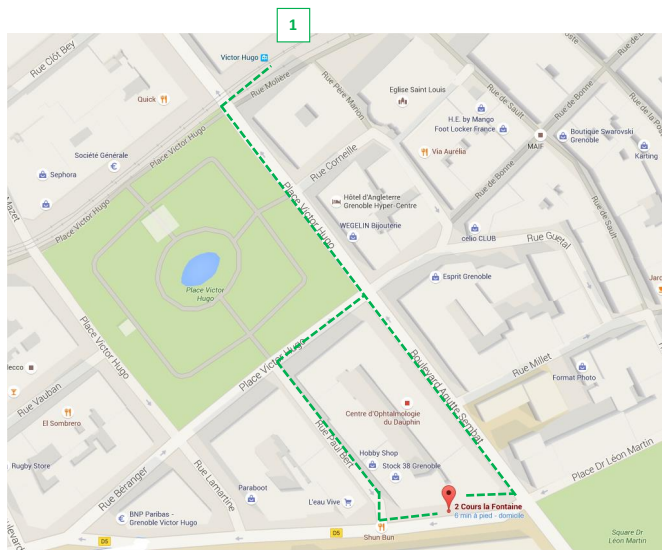
# Social program

**18:00 - 20:00, Wednesday October 7**

Welcome reception Wine & Cheese at the **Maison Jean Kuntzmann (MJK)**

**19:30 - 23:00, Thursday October 8**

Conference Gala Dinner at the **Restaurant Brasserie Chavant**



## GALA DINNER Thursday, October 8, 2015

**GALA DINNER**  
**IFAC – LPVS 2015**  
 THURSDAY, OCTOBER 8, 2015 - 20h00  
**RESTAURANT BRASSERIE CHAVANT**  
 2 COURS LA FONTAINE  
 38000 GRENOBLE  
 TEL. 04 76 87 61 83

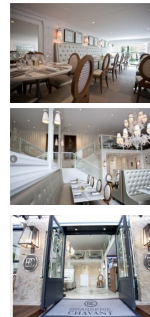
**Restaurant Brasserie Chavant**  
 2 Cours Lafontaine  
 38000 Grenoble  
 04 76 87 61 83

**By tram B,**  
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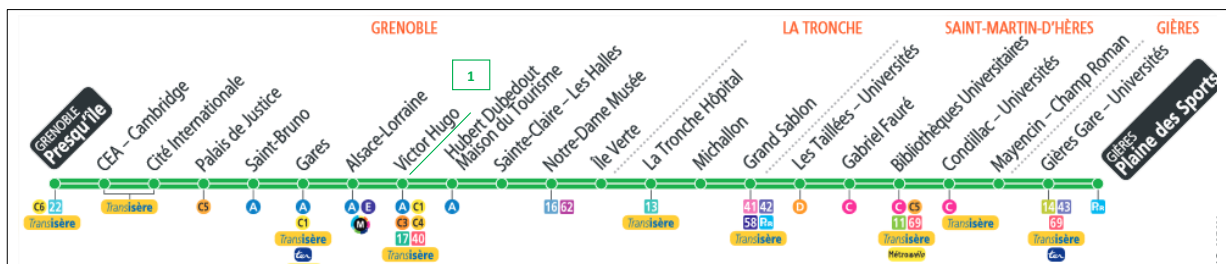
Stop – 1 "Victor Hugo" After by  
 pedestrian streets



Street Rue Molière  
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 Street Cours la Fontaine n°2



**By car,**  
 Parking "Philippeville"  
 or "Place Vaucanson"  
 or "Place Victor Hugo" »



# Plenary talks

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**17:00 - 18:00, Wednesday October 7**

**Peter Seiler**, University of Minnesota, Minneapolis, MN, USA

**Bio :** Dr. Seiler received his Ph.D. from the University of California, Berkeley in 2001. His graduate research focused on coordinated control of unmanned aerial vehicles and control over wireless networks. From 2004-2008, Dr Seiler worked at the Honeywell Research Labs on various aerospace and automotive applications including the redundancy management system for the Boeing 787, sensor fusion algorithms for automotive active safety systems and re-entry flight control laws for NASA's Orion vehicle. Since joining the University of Minnesota in 2008, Dr. Seiler has been working on fault-detection methods for safety-critical systems as well as advanced control of wind turbines and flexible aircraft.



## **Robust Analysis and Synthesis for Linear Parameter Varying Systems**

More efficient aircraft can be designed by reducing weight and structure in the wings and fuselage. This makes the aircraft more flexible leading to dynamics that change rapidly with flight condition. A flexible aircraft can be modeled as a linear parameter varying (LPV) system with an arbitrary, i.e. not necessarily rational, dependence on the scheduling parameters. Uncertainty in the modeling of the associated aeroelastic dynamics motivates the need for new analysis and synthesis tools. The approach taken in this talk is to use integral quadratic constraints (IQCs) to model the uncertainty. Standard IQC analysis theorems can be formulated in the frequency domain or with a time-domain dissipation inequality. A factorization theorem is presented that clarifies the connection between the frequency domain and time-domain approaches. Finally, the time domain approach is used to derive new analysis and synthesis conditions for LPV systems. The talk is heavily influenced by the contributions of my friend and colleague Dr. Gary Balas who passed away too soon.

# Plenary talks

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**11:00 - 12:00, Thursday October 8**

**Carsten W. Scherer**, University of Stuttgart, Germany

**Bio :** Carsten W. Scherer received the Ph.D. degree in mathematics from the University of Würzburg (Germany) in 1991. After six months of research at the University of Groningen (The Netherlands), the University of Michigan (Ann Arbor) and Washington University (St. Louis) respectively,



Dr. Scherer joined Delft University of Technology (The Netherlands) in 1993 where he held positions as an assistant and associate professor. In fall 1999 he spent a three months sabbatical as a visiting professor at the Automatic Control Laboratory of ETH Zurich. From December 2001 until February 2010 he was a full professor within the Delft Center for Systems and Control at Delft University of Technology. Since March 2010 he holds the SRC SimTech Chair Mathematical Systems Theory in the Department of Mathematics at the University of Stuttgart in Germany. His main research activities cover various topics in applying optimization techniques for developing new advanced controller design algorithms and their application to mechatronics and aerospace systems. Dr. Scherer acted as the chair of the IFAC technical committee on Robust Control (2002-2008), and he has served as an associated editor for IEEE Transactions on Automatic Control (1997-1999), Automatica (2000-2006) and Systems and Control Letters; he is currently active on the editorial board of the European Journal of Control. Since 2013 he is an IEEE fellow “for contributions to optimization-based robust controller synthesis”.

## **On the Flexibility of the Gain-Scheduling Paradigm**

Linear parameter-varying controller synthesis for gain-scheduling is either based on a polytopic or on a linear fractional representation (LFT) of the underlying system in terms of the parameters which capture the operating conditions. The purpose of this talk is to highlight the considerable flexibility of the gain-scheduling design paradigm in the LFT framework while relying on integral quadratic constraints in order to guarantee stability and performance. We address the design of multidimensional, distributed or delay-dependent controllers, with an emphasis on demonstrating the substantial benefit for the reduction of conservatism if using dynamic instead of static multipliers.

**IFAC LPV'S 2015 GRENoble October 7-9, 2015**  
**CONFERENCE PROGRAM**

<b>WEDNESDAY</b>	
<b>8.30 - 9.30</b>	REGISTRATION
<b>9.30 - 10.00</b>	WELCOME
<b>10.00 - 12.00</b>	<b>CONTROL METHODS 1</b>
<b>12.00 - 14.00</b>	LUNCH TIME
<b>14.00 - 16.20</b>	<b>AUTOMOTIVE</b>
<b>16.20 - 17.00</b>	BREAK
<b>17.00 - 18.00</b>	<b>PLENARY 1: Peter SELLER</b>
<b>18.00 - 20.00</b>	WELCOME RECEPTION WINE & CHEESE

<b>THURSDAY</b>	
<b>9.10 - 10.30</b>	<b>IDENTIFICATION</b>
<b>10.30 - 11.00</b>	BREAK
<b>11.00 - 12.00</b>	<b>PLENARY 2: Carsten SCHERER</b>
<b>12.00 - 14.00</b>	LUNCH TIME
<b>14.00 - 16.00</b>	<b>AEROSPACE</b>
<b>16.00 - 16.30</b>	BREAK
<b>16.30 - 18.10</b>	<b>CONTROL METHODS 2</b>
<b>19.30 - 23.00</b>	CONFERENCE GALA DINNER

<b>FRIDAY</b>	
<b>8.20 - 10.00</b>	<b>FDI / FTC</b>
<b>10.00 - 10.30</b>	BREAK
<b>10.30 - 12.50</b>	<b>APPLICATIONS</b>
<b>12.50 - 13.00</b>	CLOSURE
<b>13.00 - 14.30</b>	LUNCH TIME



## Content List of 1st IFAC Workshop on Linear Parameter Varying Systems

### Technical Program for Wednesday October 7, 2015

<b>WeAT1</b>		MJK
<b>CONTROL METHODS 1 (Regular Session)</b>		
Chair: Perdon, Anna Maria		Univ. Pol. Delle Marche
Co-Chair: Gomes Da Silva Jr, Joao Manoel		Univ. Federal Do Rio Grande Do Sul (UFRGS)
10:00-10:20		WeAT1.1
<i>The Disturbance Decoupling Problem with Quadratic Stability for LPV Systems</i> , pp. 1-6.		
Conte, Giuseppe		Univ. Pol. Delle Marche
Perdon, Anna Maria		Univ. Pol. Delle Marche
Zattoni, Elena		Univ. of Bologna
10:20-10:40		WeAT1.2
<i>Numerical Computation of Lyapunov Function for Hyperbolic PDE Using LMI Formulation and Polytopic Embeddings</i> , pp. 7-12.		
Lamare, Pierre-Olivier		Univ. Joseph Fourier
Girard, Antoine		Univ. Joseph Fourier
Prieur, Christophe		GIPSA-Lab / CNRS
10:40-11:00		WeAT1.3
<i>Toward Nonlinear Tracking and Rejection Using LPV Control</i> , pp. 13-18.		
Scorletti, Gerard		Ec. Centrale De Lyon
Fromion, Vincent		INRA
de Hillerin, Safta		SUPELEC
11:00-11:20		WeAT1.4
<i>Sampled-Data LPV Control: A Looped Functional Approach</i> , pp. 19-24.		
Gomes Da Silva Jr, Joao Manoel		Univ. Fed. Do Rio Grande Do Sul (UFRGS)
Moraes, Vitor Mateus		Univ. Fed. Do Rio Grande Do Sul (UFRGS)
Flores, Jeferson Vieira		Univ. Fed. Do Rio Grande Do Sul (UFRGS)
Kimura Palmeira, Alessandra Helena		Univ. Fed. Do Rio Grande Do Sul (UFRGS)
11:20-11:40		WeAT1.5
<i>Shifting Linear Quadratic Control of Constrained Continuous-Time Descriptor LPV Systems</i> , pp. 25-30.		
Rotondo, Damiano		Univ. Pol. De Catalunya
Nejjari, Fatiha		Univ. Pol. De Catalunya
Puig, Vicenc		Univ. Pol. De Catalunya
11:40-12:00		WeAT1.6
<i>Gain-Scheduled State Feedback Controllers for Discrete-Time LPV Systems Using Scheduling Parameters Affected by Absolute and Proportional Uncertainties</i> , pp. 31-36.		
Sato, Masayuki		Japan Aerospace Exploration Agency
<b>WePT1</b>		MJK
<b>AUTOMOTIVE (Regular Session)</b>		
Chair: Lauber, Jimmy		Univ. of Valenciennes
Co-Chair: Morales-Menendez, Ruben		Tecnologico De Monterrey, Campus Monterrey

14:00-14:20		WePT1.1
<i>Identification of a Linear Parameter Varying Driver Model for the Detection of Distraction</i> , pp. 37-42.		
Ameyoe, Ablamvi		IRCCyN, Renault SAS
Chevrel, Philippe		IRCCyN / Ec. Des Mines De Nantes
Le Carpentier, Eric		IRCCyN / Ec. Centrale De Nantes
Mars, Franck		IRCCyN / Ec. Centrale De Nantes
Illy, Hervé		Renault SAS
14:20-14:40		WePT1.2
<i>Simple Discrete-Time Switched H-Infinity Optimal Control: Application for Lateral Vehicle Control</i> , pp. 43-48.		
Menhour, Lghani		École Des Mines De Paris
Koenig, Damien		Grenoble-INP / GIPSA-Lab
D'Andrea-Novet, Brigitte		École Des Mines De Paris
14:40-15:00		WePT1.3
<i>Reconfigurable Fault-Tolerant Control of In-Wheel Electric Vehicles with Steering System Failure</i> , pp. 49-54.		
Mihaly, Andras		MTA-SZTAKI
Gaspar, Peter		MTA-SZTAKI
15:00-15:20		WePT1.4
<i>Force Control System for an Automotive Semi-Active Suspension</i> , pp. 55-60.		
Vivas Lopez, Carlos Alberto		Tecnologico De Monterrey, Campus Monterrey
Hernandez-Alcantara, Diana		Tecnologico De Monterrey, Campus Monterrey
Nguyen, Manh Quan		Univ. Grenoble Alpes / GIPSA-Lab
Morales-Menendez, Ruben		Tecnologico De Monterrey, Campus Monterrey
Sename, Olivier		Grenoble-INP / GIPSA-Lab
15:20-15:40		WePT1.5
<i>LPV-Based Variable-Geometry Suspension Control Considering Nonlinear Tyre Characteristics</i> , pp. 61-66.		
Nemeth, Balazs		MTA-SZTAKI
Gaspar, Peter		MTA-SZTAKI
15:40-16:00		WePT1.6
<i>Semi-Active Suspension Control with LPV Mass Adaptation</i> , pp. 67-72.		
Tudon-Martinez, Juan Carlos		Univ. De Monterrey
Hernandez-Alcantara, Diana		Tecnologico De Monterrey, Campus Monterrey
Morales-Menendez, Ruben		Tecnologico De Monterrey, Campus Monterrey
16:00-16:20		WePT1.7
<i>Transmitted Torque Observer Applied to Real Time Engine and Clutch Torque Estimation</i> , pp. 73-78.		
Losero, Remi		Univ. of Valenciennes and Hainaut Cambresis
Lauber, Jimmy		Univ. of Valenciennes and Hainaut Cambresis
Guerra, Thierry Marie		Univ. of Valenciennes and Hainaut Cambresis

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**WePlenary1T1** MJK

**PLENARY TALK: Peter SEILER** (Plenary Session)

Chair: Lovera, Marco Pol. Di Milano

Co-Chair: Sename, Olivier Grenoble-INP, GIPSA-Lab

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17:00-18:00 WePlenary1T1.1

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*Robust Analysis and Synthesis for Linear Parameter Varying Systems\**.

Seiler, Peter Univ. of Minnesota

Technical Program for Thursday October 8, 2015

<b>ThAT1</b>		MJK
<b>IDENTIFICATION (Regular Session)</b>		
Chair: Tóth, Roland	Eindhoven Univ. of Tech	
Co-Chair: Mercère, Guillaume	Poitiers Univ	
09:10-09:30	ThAT1.1	
<i>Gray-Box LPV Model Identification of a 2-DoF Surgical Robotic Manipulator by Using an <math>H_\infty</math>-Norm-Based Local Approach</i> , pp. 79-84.		
Vizer, Daniel	Univ. of Tech. and Ec. of Budapest	
Mercère, Guillaume	Poitiers Univ	
Laroche, Edouard	Strasbourg Univ	
09:30-09:50	ThAT1.2	
<i>A Kernel-Based Approach to MIMO LPV State-Space Identification and Application to a Nonlinear Process System</i> , pp. 85-90.		
Rizvi, Syed	Univ. of Georgia	
Mohammadpour, Javad	Univ. of Georgia	
Tóth, Roland	Eindhoven Univ. of Tech	
Meskin, Nader	Qatar Univ	
09:50-10:10	ThAT1.3	
<i>Estimation of LPV-SS Models with Static Dependency Using Correlation Analysis</i> , pp. 91-96.		
Cox, Pepijn Bastiaan	Eindhoven Univ. of Tech	
Tóth, Roland	Eindhoven Univ. of Tech	
Petreczky, Mihaly	Ec. Des Mines De Douai	
10:10-10:30	ThAT1.4	
<i>A Kernel Based Approach for LPV Subspace Identification</i> , pp. 97-102.		
Proimadis, Ioannis	Delft Univ. of Tech	
Bijl, Hildo	Delft Univ. of Tech	
van Wingerden, Jan-Willem	Delft Univ. of Tech	

<b>ThPlenary2T1</b>		MJK
<b>PLENARY TALK: Carsten SCHERER (Plenary Session)</b>		
Chair: Sename, Olivier	Grenoble-INP, GIPSA-Lab	
Co-Chair: Lovera, Marco	Pol. Di Milano	
11:00-12:00	ThPlenary2T1.1	
<i>On the Flexibility of the Gain-Scheduling Paradigm*</i> .		
Scherer, Carsten W.	Univ. of Stuttgart	

<b>ThP1T1</b>		MJK
<b>AEROSPACE (Regular Session)</b>		
Chair: Marcos, Andres	Univ. of Bristol	
Co-Chair: Poussot-Vassal, Charles	ONERA	
14:00-14:20	ThP1T1.1	
<i>Linear Parameter Varying Techniques Applied to Aeroservoelastic Aircraft: In Memory of Gary Balas</i> , pp. 103-108.		
Pfifer, Harald	Univ. of Minnesota	
Moreno, Claudia P.	Univ. of Minnesota	
Theis, Julian	Hamburg Univ. of Tech	
Kotikalpudi, Aditya	Univ. of Minnesota	
Gupta, Abhineet	Univ. of Minnesota	

Takarics, Bela	Univ. of Minnesota	
Seiler, Peter	Univ. of Minnesota	
14:20-14:40	ThP1T1.2	
<i>Rotorcraft Vibration Control: Adaptive vs LPV Methods</i> , pp. 109-114.		
Mura, Roberto	Pol. Di Milano	
Lovera, Marco	Pol. Di Milano	
14:40-15:00	ThP1T1.3	
<i>LPV Modeling and LFT Uncertainty Identification for Robust Analysis: Application to the VEGA Launcher During Atmospheric Phase</i> , pp. 115-120.		
Marcos, Andres	Univ. of Bristol	
Bennani, Samir	European Space Agency	
Roux, Christophe	ELV	
valli, monica	ELV	
15:00-15:20	ThP1T1.4	
<i>LPV Model Identification for Flutter Prediction: A Comparison of Methods</i> , pp. 121-126.		
Visser, Mart	Delft Univ. of Tech	
Navalkar, Sachin	Delft Univ. of Tech	
van Wingerden, Jan-Willem	Delft Univ. of Tech	
15:20-15:40	ThP1T1.5	
<i>LPV Control for Multi-Harmonic Microvibration Attenuation: Application to High Stability Space Missions</i> , pp. 127-132.		
Preda, Valentin	Univ. of Bordeaux	
Cieslak, Jérôme	Univ. of Bordeaux	
Henry, David	Univ. of Bordeaux	
Bennani, Samir	European Space Agency	
Falcoz, Alexandre	EADS Astrium	
15:40-16:00	ThP1T1.6	
<i>Parametric Reduced Order Dynamical Model Construction of a Fluid Flow Control Problem</i> , pp. 133-138.		
Poussot-Vassal, Charles	ONERA	
Sipp, Denis	ONERA	

<b>ThP2T1</b>		MJK
<b>CONTROL METHODS 2 (Regular Session)</b>		
Chair: Guelton, Kevin	Univ. De Reims Champagne-Ardenne	
Co-Chair: Formentin, Simone	Pol. Di Milano	
16:30-16:50	ThP2T1.1	
<i>LPVTools: A Toolbox for Modeling, Analysis, and Synthesis of Parameter Varying Control Systems</i> , pp. 139-145.		
Hjartarson, Arnar	MUSYN Inc	
Seiler, Peter	Univ. of Minnesota	
Packard, Andrew K.	Univ. of California at Berkeley	
16:50-17:10	ThP2T1.2	
<i>Nonparametric LPV Data-Driven Control</i> , pp. 146-151.		
Formentin, Simone	Pol. Di Milano	
Piga, Dario	IMT Inst. for Advanced Studies Lucca	
Tóth, Roland	Eindhoven Univ. of Tech	
Savaresi, Sergio	Pol. Di Milano	
17:10-17:30	ThP2T1.3	
<i>Generalized Dynamic Observers for LPV Singular Systems</i> , pp. 152-157.		
Osorio Gordillo, Gloria Lilia	CRAN, Univ. De Lorraine	
Darouach, Mohamed	CRAN, Univ. De Lorraine	



Boutat-Baddas, Latifa	CRAN, Univ. De Lorraine
Astorga Zaragoza, Carlos Manuel	Centro Nacional De Investigación Y Desarrollo Tecnológico

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17:30-17:50 ThP2T1.4

*A Networked-Based MPC Architecture for Constrained LPV Systems*, pp. 158-163.

Casavola, Alessandro	Univ. Della Calabria
Lucia, Walter	Univ. Della Calabria
Tedesco, Francesco	Univ. Della Calabria

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17:50-18:10 ThP2T1.5

*Quadratic Design of D-Stabilizing Non-PDC Controllers for Quasi-LPV/T-S Models*, pp. 164-169.

Cherifi, Abdelmadjid	CReSTIC, Univ. De Reims Champagne-Ardenne
Guelton, Kevin	CReSTIC, Univ. De Reims Champagne-Ardenne
Arcese, Laurent	CReSTIC, Univ. De Reims Champagne-Ardenne

Technical Program for Friday October 9, 2015

FrA1T1	MJK
<b>FDI / FTC (Regular Session)</b>	
Chair: Theilliol, Didier	Univ. of Lorraine
Co-Chair: Martinez Molina, John J.	Grenoble-INP, GIPSA-Lab
08:20-08:40	FrA1T1.1
<i>Null-Space Computation for qLPV Systems</i> , pp. 170-175.	
Szabo, Zoltan	MTA-SZTAKI
Peni, Tamas	MTA-SZTAKI
Bokor, Jozsef	MTA-SZTAKI
08:40-09:00	FrA1T1.2
<i>Robust Sensor Fault Detection and Isolation of an Aneerobic Bioreactor Modeled As a Descriptor-LPV System</i> , pp. 176-181.	
Lopez-Estrada, Francisco-Ronay	Tecnológico Nacional De Mexico. Inst. Tec De Tuxtla
Castañon-Gonzalez, José Humberto	Inst. Tec. De Tuxtla Gutierrez
Ponsart, Jean-Christophe	CRAN, Univ. De Lorraine
Theilliol, Didier	CRAN, Univ. De Lorraine
Astorga Zaragoza, Carlos Manuel	Centro Nacional De Investigación Y Desarrollo Tecnológico
09:00-09:20	FrA1T1.3
<i>Minimal RPI Sets Computation for Polytopic Systems Using the Bounded-Real Lemma and a New Shrinking Procedure</i> , pp. 182-187.	
Martinez Molina, John J.	Grenoble-INP, GIPSA-Lab
09:20-09:40	FrA1T1.4
<i>Fault Detection for LPV Systems: Loop Shaping H-Approach</i> , pp. 188-193.	
Farhat, Ahmad	Univ. Grenoble Alpes
Koenig, Damien	Grenoble-INP, GIPSA-Lab
Sename, Olivier	Grenoble-INP, GIPSA-Lab
09:40-10:00	FrA1T1.5
<i>A Switched LPV Observer for Actuator Fault Estimation</i> , pp. 194-199.	
Nguyen, Manh Quan	Univ. Grenoble Alpes, GIPSA-Lab
Sename, Olivier	Grenoble-INP, GIPSA-Lab
Dugard, Luc	Gipsa-Lab, CNRS Grenoble

FrA2T1	MJK
<b>APPLICATIONS (Regular Session)</b>	
Chair: Zasadzinski, Michel	CRAN, Univ. De Lorraine
Co-Chair: Karimi, Alireza	Ec. Pol. Fédérale De Lausanne
10:30-10:50	FrA2T1.1
<i>Linear Parameter-Varying Control of a Copolymerization Reactor</i> , pp. 200-206.	
Abbas, Hossameldin	Assiut Univ
Mahmoud Seddik	
Rahme, Sandy	Qatar Univ
Meskin, Nader	Qatar Univ
Hoffmann, Christian	Hamburg Univ. of Tech
Tóth, Roland	Eindhoven Univ. of Tech
Mohammadpour, Javad	Univ. of Georgia
10:50-11:10	FrA2T1.2
<i>Iterative Feedback Tuning of an LPV Feedforward Controller for Wind Turbine Load Alleviation</i> , pp. 207-212.	

Navalkar, Sachin	Delft Univ. of Tech
van Wingerden, Jan-Willem	Delft Univ. of Tech
11:10-11:30	FrA2T1.3
<i>An H-Infinity LPV Control for a Class of LPV Systems Using a Descriptor Approach. Application to a Wind Turbine Model</i> , pp. 213-217.	
Souley Ali, Harouna	CRAN, Univ. De Lorraine
Darouach, Mohamed	CRAN, Univ. De Lorraine
Zasadzinski, Michel	CRAN, Univ. De Lorraine
Alma, Marouane	CRAN, Univ. De Lorraine
11:30-11:50	FrA2T1.4
<i>Decentralized Robust Control of Power Grids Using LPV-Models of DAE-Systems</i> , pp. 218-223.	
Schaab, Konstantin	Univ. of Kassel
Stursberg, Olaf	Univ. of Kassel
11:50-12:10	FrA2T1.5
<i>Switching Robust Controllers for Automatic Regulation of Postoperative Hypertension Using Vasodilator Drug Infusion Rate</i> , pp. 224-229.	
Ahmed, Saeed	Bilkent Univ
Ozby, Hitay	Bilkent Univ
12:10-12:30	FrA2T1.6
<i>Fixed-Order Linear Parameter Varying Controller Design for a 2DOF Gyroscope</i> , pp. 230-235.	
Emedi, Zlatko	Etel Sa
Karimi, Alireza	Ec. Pol. Fédérale De Lausanne
12:30-12:50	FrA2T1.7
<i>Design and Experimental Tests of an LPV Power System Stabilizer on a 10kVA Small-Scale Generating Unit</i> , pp. 236-241.	
Nogueira, Fabrício Gonzalez	Univ. Federal Do Ceará
Barra Jr., Walter	Univ. Federal Do Pará
Da Costa Jr., Carlos	Univ. Federal Do Pará
Barreiros, José	Univ. Federal Do Pará
De Lana, Janio	Centrais Elétricas Do Norte Do Brasil



## Book of Abstracts of 1st IFAC Workshop on Linear Parameter Varying Systems

### Technical Program for Wednesday October 7, 2015

WeAT1	MJK
<b>CONTROL METHODS 1 (Regular Session)</b>	
Chair: Perdon, Anna Maria	Univ. Pol. Delle Marche
Co-Chair: Gomes Da Silva Jr, Joao Manoel	Univ. Federal Do Rio Grande Do Sul (UFRGS)
10:00-10:20	WeAT1.1
<i>The Disturbance Decoupling Problem with Quadratic Stability for LPV Systems</i> , pp. 1-6	
Conte, Giuseppe	Univ. Pol. Delle Marche
Perdon, Anna Maria	Univ. Pol. Delle Marche
Zattoni, Elena	Univ. of Bologna
<p>We consider the problem of decoupling the output from a disturbance by means of a quadratically stabilizing state feedback for a general class of linear parameter varying systems. Solutions are characterized from the structural point of view in geometric terms. Under suitable hypotheses, a checkable sufficient condition and a viable procedure for constructing solutions are provided.</p>	
10:20-10:40	WeAT1.2
<i>Numerical Computation of Lyapunov Function for Hyperbolic PDE Using LMI Formulation and Polytopic Embeddings</i> , pp. 7-12	
Lamare, Pierre-Olivier	Univ. Joseph Fourier
Girard, Antoine	Univ. Joseph Fourier
Prieur, Christophe	GIPSA-Lab / CNRS
<p>We consider the problem of stability analysis and control synthesis for first-order hyperbolic linear PDEs over a bounded interval with spatially varying coefficients. We propose LMI-based conditions for the stability and for the design of boundary and distributed control for this class of systems. These LMI-based conditions involve an infinite number of LMI. Hence, we show how to overapproximate these constraints using polytopic embeddings to reduce the problem to a finite number of LMI. We show the effectiveness of the overapproximation with several examples.</p>	
10:40-11:00	WeAT1.3
<i>Toward Nonlinear Tracking and Rejection Using LPV Control</i> , pp. 13-18	
Scorletti, Gerard	Ec. Centrale De Lyon
Fromion, Vincent	INRA
de Hillerin, Safta	SUPELEC
<p>(Quasi) LPV control methods and more generally L2 gain control methods, referred to as nonlinear H infinity control methods, are usually applied in order to ensure reference tracking and disturbance rejection. In this paper, we exhibit a counterexample that reveals that these specifications can not be ensured by these methods. We then propose a new LPV based approach in order to a priori ensure these specifications by combining the LPV method with the incremental L2 gain analysis of nonlinear performance. Its benefit is illustrated on the counterexample.</p>	
11:00-11:20	WeAT1.4
<i>Sampled-Data LPV Control: A Looped Functional Approach</i> , pp. 19-24	
Gomes Da Silva Jr, Joao Manoel	Univ. Fed. Do Rio Grande Do Sul (UFRGS)
Moraes, Vitor Mateus	Univ. Fed. Do Rio Grande Do Sul (UFRGS)
Flores, Jeferson Vieira	Univ. Fed. Do Rio Grande Do Sul (UFRGS)
Kimura Palmeira, Alessandra Helena	Univ. Fed. Do Rio Grande Do Sul (UFRGS)

This paper addresses the problem of stability and stabilization of

sampled-data linear parameter varying (LPV) control systems. It is explicitly assumed that the LPV-controller is updated only at the sampling instants and that the control signal is kept constant between two consecutive samples by means of a zero order holder, while the plant and the scheduling parameter evolve continuously in time. In this case, conditions that allow to compute a sampled-data LPV state feedback control law that ensures the asymptotic stability of the closed-loop system, provided that the intersampling interval respect some bounds, are proposed in a quasi Linear Matrix Inequality (LMI) form (i.e. they are LMIs provided a scalar parameters is fixed). The approach is based on a polytopic modeling of the LPV system and the use of a parameter dependent looped-functional to take into account the sampling effects. Both periodic and aperiodic sampling cases can be handled. A numerical example illustrates the application of the proposed methodology

11:20-11:40	WeAT1.5
<i>Shifting Linear Quadratic Control of Constrained Continuous-Time Descriptor LPV Systems</i> , pp. 25-30	
Rotondo, Damiano	Univ. Pol. De Catalunya
Nejjari, Fatiha	Univ. Pol. De Catalunya
Puig, Vicenc	Univ. Pol. De Catalunya

Recently, the concept of shifting linear quadratic control (SLQC), where some varying parameters are introduced and used to schedule the weighting matrices of a quadratic cost function, has been introduced. This paper further explores this concept by considering the presence of constraints in the system to be controlled. In particular, two types of constraints are considered: a) algebraic constraints between the variables of the system; and b) constraints on the allowed values for the input and the state variables. The proposed solution, investigated under the descriptor linear parameter varying (D-LPV) framework, requires solving a set of linear matrix inequalities (LMIs), a problem for which efficient solvers are available nowadays. A numerical example illustrates the application of the proposed theory.

11:40-12:00	WeAT1.6
<i>Gain-Scheduled State Feedback Controllers for Discrete-Time LPV Systems Using Scheduling Parameters Affected by Absolute and Proportional Uncertainties</i> , pp. 31-36	
Sato, Masayuki	Japan Aerospace Exploration Agency

This paper is concerned with the design problem of Gain-Scheduled State Feedback (GSSF) controllers for discrete-time Linear Parameter-Varying (LPV) systems. By considering that exact scheduling parameters are not available in many practical systems, the scheduling parameters provided to GSSF controllers are supposed to be affected by absolute as well as proportional uncertainties. We introduce a set covering the admissible set for the pair of scheduling parameters and the inexact ones, and propose a design method of GSSF controllers using the set. Numerical examples illustrate the effectiveness and possible conservatism of our method.

WePT1	MJK
<b>AUTOMOTIVE (Regular Session)</b>	
Chair: Lauber, Jimmy	Univ. of Valenciennes
Co-Chair: Morales-Menendez, Ruben	Tecnologico De Monterrey, Campus Monterrey
14:00-14:20	WePT1.1
<i>Identification of a Linear Parameter Varying Driver Model for the Detection of Distraction</i> , pp. 37-42	
Ameyoe, Ablamvi	IRCCyN, Renault SAS
Chevrel, Philippe	IRCCyN / Ec. Des Mines De Nantes

Le Carpentier, Eric	IRCCyN / Ec. Centrale De Nantes
Mars, Franck	IRCCyN / Ec. Centrale De Nantes
Illy, Hervé	Renault SAS

This study investigates a real-time identification of a LPV Cybernetic Driver Model (CDM), using the Unscented Kalman Filter (UKF). Unlike an iterative identification, dealing with packets of input-output data, the method considered is recursive identification dealing with the actual input-output data, making explicit the parametric changes along time. The two identification schemes are implemented and the cybernetic driver model capability to predict or to estimate the driver steering was evaluated. The possibility of the recursive identification, when applied to the cybernetic model, to help for distraction diagnosis is finally evoked. The variations of the driver model parameters are shown to be significantly associated with driver distraction.

14:20-14:40 WePT1.2

*Simple Discrete-Time Switched H-Infinity Optimal Control: Application for Lateral Vehicle Control*, pp. 43-48

Menhour, Lghani	École Des Mines De Paris
Koenig, Damien	Grenoble-INP / GIPSA-Lab
D'Andrea-Novet, Brigitte	École Des Mines De Paris

This paper presents a switched H-infinity optimal control for a class of discrete-time switched linear systems. All sufficient conditions of the existence of the control law are proved and given in terms of LMI for any switching. Moreover, the proofs are established using an H-infinity norm and switched Lyapunov functions. Its performances are shown through a steering vehicle control application. In fact, the vehicle models are affected by several parameter variations like longitudinal speed, cornering stiffnesses coefficients. The validation step is conducted using real data acquired by a laboratory car under high lateral loads.

14:40-15:00 WePT1.3

*Reconfigurable Fault-Tolerant Control of In-Wheel Electric Vehicles with Steering System Failure*, pp. 49-54

Mihaly, Andras	MTA-SZTAKI
Gaspar, Peter	MTA-SZTAKI

The paper deals with the robust and fault tolerant control of an in-wheel electric vehicle, operated by four independently actuated in-wheel motors and steer-by-wire steering system. The goal of the design is to realize velocity and road trajectory tracking of the in-wheel vehicle, even during a fault event in the steer-by-wire steering system. When such a fault is detected, the control system is reconfigured and the torque allocation of the in-wheel engines is recalculated to substitute for the yaw moment originally generated by the steering system. Thus, the vehicle is able to follow the designed path and velocity solely with torque vectoring generated by the independently-controlled in-wheel motors. The high-level motion control of the vehicle is realized founded on the LPV framework, while the reconfiguration is based on constrained optimization techniques. The operation of the designed control system is demonstrated in a CarSim simulation environment.

15:00-15:20 WePT1.4

*Force Control System for an Automotive Semi-Active Suspension*, pp. 55-60

Vivas Lopez, Carlos Alberto	Tecnologico De Monterrey, Campus Monterrey
Hernandez-Alcantara, Diana	Tecnologico De Monterrey, Campus Monterrey
Nguyen, Manh Quan	Univ. Grenoble Alpes / GIPSA-Lab
Morales-Menendez, Ruben	Tecnologico De Monterrey, Campus Monterrey
Sename, Olivier	Grenoble-INP / GIPSA-Lab

A new semi-active suspension control system is proposed. This control system includes a Linear Parameter Varying (LPV) controller which was designed to improve the ride comfort. It also

incorporates a Force Control System (FCS) to transform the force command from the LPV controller to an input signal for the Electro-Rheological (ER) semi-active damper. This FCS was assessed by its tracking performance of the desired force command, with a 7% of tracking error. Then the semi-active control system was evaluated in a Quarter of Vehicle (QoV) model under two tests: a Bump and a Road Profile. The results were a reduction up to 19% (Bump test) and 29% (Road Profile test), of the sprung mass position compared with a passive suspension. Additionally, an improvement up to 14% was obtained when compared with a LPV controller using a simple model inversion Force-Manipulation transformation.

15:20-15:40 WePT1.5

*LPV-Based Variable-Geometry Suspension Control Considering Nonlinear Tyre Characteristics*, pp. 61-66

Nemeth, Balazs	MTA-SZTAKI
Gaspar, Peter	MTA-SZTAKI

The paper proposes a method for the LPV-based (Linear Parameter-Varying) control design of the variable-geometry suspension system. The tilting actuation of the front wheel improves the lateral dynamics of the vehicle and assists for the driver in avoiding critical situations. The novelty of the method is the consideration of the nonlinearities in the tyre characteristics. The tyre forces are approximated by polynomials, which are used in the linearizing of the vehicle model. A parameter-varying vehicle model is derived, on which a robust LPV control is designed. The proposed method improves the performances of vehicle dynamics, and handles the critical maneuvers caused by e.g. a skidding car and high velocities. The proposed method is illustrated through CarSim simulation examples.

15:40-16:00 WePT1.6

*Semi-Active Suspension Control with LPV Mass Adaptation*, pp. 67-72

Tudon-Martinez, Juan Carlos	Univ. De Monterrey
Hernandez-Alcantara, Diana	Tecnologico De Monterrey, Campus Monterrey
Morales-Menendez, Ruben	Tecnologico De Monterrey, Campus Monterrey

A novel control system for an automotive semi-active suspension based on a Quarter of Vehicle (QoV) model is proposed. In typical conditions the mass of the vehicle body varies due to several variables, such as the number of passengers, the vehicle load, etc. These variations can lead to undesirable responses even if the controller was adequately tuned using a nominal model. In order to improve this situation a controller which actively adapts to vehicle body mass variations can be used. In this article a control scheme based on the Linear Parameter-Varying (LPV) framework is proposed. This approach considers the nonlinear behavior of the damper and variations on the sprung mass as scheduling parameters. The vehicle body mass is online estimated using the Recursive Least Squares algorithm. Simulations of a QoV model of a pickup truck which includes an experimental magneto-rheological damper model were carried out in order to evaluate the proposed scheme. Results in the frequency and time domain show the effectiveness of the proposed controller compared to an uncontrolled damper and a standard LPV controller without mass adaptation. The comfort is improved over 25% using the proposed scheme when the vehicle body mass changes.

16:00-16:20 WePT1.7

*Transmitted Torque Observer Applied to Real Time Engine and Clutch Torque Estimation*, pp. 73-78

Losero, Remi	Univ. of Valenciennes and Hainaut Cambresis
Lauber, Jimmy	Univ. of Valenciennes and Hainaut Cambresis
Guerra, Thierry Marie	Univ. of Valenciennes and Hainaut Cambresis

In automation control system applications, the transmitted engine and clutch torque are unavoidable information for the control

strategies. For example, these information are required to engine control, hybrid vehicle and automated transmission management. An angular domain discrete observer is proposed to estimate the transmitted torque from incremental encoders which are already implemented on the vehicle. Some simulation results of transmitted clutch torque estimation are presented as instantaneous brake engine torque and clutch torque estimation on real data. This proposed torque estimation method based on shaft angular deformation permits to obtain accurate results in different automotive applications.

<b>WePlenary1T1</b>	MJK
<b>PLENARY TALK: Peter SEILER (Plenary Session)</b>	

Chair: Lovera, Marco	Pol. Di Milano
Co-Chair: Sename, Olivier	Grenoble-INP, GIPSA-Lab

17:00-18:00	WePlenary1T1.1
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*Robust Analysis and Synthesis for Linear Parameter Varying Systems\**

Seiler, Peter	Univ. of Minnesota
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More efficient aircraft can be designed by reducing weight and structure in the wings and fuselage. This makes the aircraft more flexible leading to dynamics that change rapidly with flight condition. A flexible aircraft can be modeled as a linear parameter varying (LPV) system with an arbitrary, i.e. not necessarily rational, dependence on the scheduling parameters. Uncertainty in the modeling of the associated aeroelastic dynamics motivates the need for new analysis and synthesis tools. The approach taken in this talk is to use integral quadratic constraints (IQCs) to model the uncertainty. Standard IQC analysis theorems can be formulated in the frequency domain or with a time-domain dissipation inequality. A factorization theorem is presented that clarifies the connection between the frequency domain and time-domain approaches. Finally, the time domain approach is used to derive new analysis and synthesis conditions for LPV systems. The talk is heavily influenced by the contributions of my friend and colleague Dr. Gary Balas who passed away too soon.

**Technical Program for Thursday October 8, 2015**

**ThAT1** MJK  
**IDENTIFICATION (Regular Session)**

Chair: Tóth, Roland Eindhoven Univ. of Tech  
 Co-Chair: Mercère, Guillaume Poitiers Univ

09:10-09:30 ThAT1.1

*Gray-Box LPV Model Identification of a 2-DoF Surgical Robotic Manipulator by Using an  $H^\infty$ -Norm-Based Local Approach*, pp. 79-84

Vizer, Daniel Univ. of Tech. and Ec. of Budapest  
 Mercère, Guillaume Poitiers Univ  
 Laroche, Edouard Strasbourg Univ

Identifying a linear parameter-varying (LPV) model of a non-linear system from local experiments (i.e., experiments with small displacements around given positions) is a problem which still deserves attention. Rather than building a model either from the law of physics or from experimental data independently, the combination of an analytic and an experimental approach is used in this paper to identify an LPV model of a 2-DoF flexible surgical robotic manipulator. This LPV model is more precisely estimated by applying a dedicated  $H^\infty$ -norm-based technique to yield a final parameter dependent model written as a linear fractional representation (LFR). This contribution demonstrates the effectiveness of the used  $H^\infty$ -norm-based identification

09:30-09:50 ThAT1.2

*A Kernel-Based Approach to MIMO LPV State-Space Identification and Application to a Nonlinear Process System*, pp. 85-90

Rizvi, Syed Univ. of Georgia  
 Mohammadpour, Javad Univ. of Georgia  
 Tóth, Roland Eindhoven Univ. of Tech  
 Meskin, Nader Qatar Univ

This paper first describes the development of a nonparametric identification method for linear parameter-varying (LPV) state-space models and then applies it to a nonlinear process system. The proposed method uses kernel-based least-squares support vector machines (LS-SVM). While parametric identification methods require proper selection of basis functions in order to avoid over-parametrization or structural bias, the problem of variance-bias tradeoff is avoided by estimating the functional dependencies of the state-space representation on the LPV scheduling variables using measured input and output data under the LS-SVM framework. The proposed formulation allows for LS-SVM to reconstruct and uncover static, as well as dynamic dependencies on scheduling variables in multi-input multi-output (MIMO) LPV models. This is achieved by assuming that the states are measurable, which is a common scenario during online control of many chemical processes described by lumped parameter models. The proposed method does not require an explicit declaration of the feature maps of the nonlinearities of the assumed model structure; instead, it requires the selection of a nonlinear kernel function and tuning its parameters. The developed identification method is applied to a continuous stirred tank reactor (CSTR) model under realistic noise conditions. Another numerical example along with the CSTR system illustrates the performance of the proposed algorithm under both static and dynamic dependence on the scheduling variables.

09:50-10:10 ThAT1.3

*Estimation of LPV-SS Models with Static Dependency Using Correlation Analysis*, pp. 91-96

Cox, Pepijn Bastiaan Eindhoven Univ. of Tech  
 Tóth, Roland Eindhoven Univ. of Tech  
 Petreczky, Mihaly Ec. Des Mines De Douai

Many global identification approaches described in the literature

for estimating linear parameter-varying (LPV) discrete-time state-space (SS) models with affine dependence on the scheduling parameter suffer heavily from the curse of dimensionality, making identification of moderate sized systems computationally intensive or infeasible. In this paper, we present a novel two-step approach to estimate LPV-SS models based on a single data set with varying scheduling signal by combining 1) LPV correlation analysis, and 2) a deterministic LPV realization scheme. Step 1 includes the estimation of the sub-Markov parameters of the system using correlation analysis of the involved signals. Subsequently, for Step 2, this paper presents a novel basis reduced exact Ho-Kalman like realization scheme, which uses only sub parts of the extended Hankel matrix. Therefore, the computational complexity is significantly reduced compared to the full scheme. To demonstrate that the basis reduction does not lead to a loss in performance, a simulation study is provided.

10:10-10:30 ThAT1.4

*A Kernel Based Approach for LPV Subspace Identification*, pp. 97-102

Proimadis, Ioannis Delft Univ. of Tech  
 Bijl, Hildo Delft Univ. of Tech  
 van Wingerden, Jan-Willem Delft Univ. of Tech

We present a Linear Parameter Varying (LPV) identification method that takes advantage of the recent developments in the Machine Learning community. More specifically, a Radial Basis Function kernel is used to model the predictor's impulse response of an LPV model and the involved hyperparameters are estimated via a marginal likelihood maximization algorithm. This step is followed by the estimation of the predictor's impulse response coefficients, evaluated at the training points. Finally, these values are used to estimate the LPV model equivalent Markov parameters. From this point, the algorithm follows the same steps as in the LPV-PBSIDopt algorithm. Simulation results verify that this algorithm can improve the accuracy of the estimated model with respect to the state-of-the-art LPV subspace methods.

**ThPlenary2T1** MJK  
**PLENARY TALK: Carsten SCHERER (Plenary Session)**

Chair: Sename, Olivier Grenoble-INP, GIPSA-Lab  
 Co-Chair: Lovera, Marco Pol. Di Milano

11:00-12:00 ThPlenary2T1.1

*On the Flexibility of the Gain-Scheduling Paradigm\**

Scherer, Carsten W. Univ. of Stuttgart

Linear parameter-varying controller synthesis for gain-scheduling is either based on a polytopic or on a linear fractional representation (LFT) of the underlying system in terms of the parameters which capture the operating conditions. The purpose of this talk is to highlight the considerable flexibility of the gain-scheduling design paradigm in the LFT framework while relying on integral quadratic constraints in order to guarantee stability and performance. We address the design of multidimensional, distributed or delay-dependent controllers, with an emphasis on demonstrating the substantial benefit for the reduction of conservatism if using dynamic instead of static multipliers.

**ThP1T1** MJK  
**AEROSPACE (Regular Session)**

Chair: Marcos, Andres Univ. of Bristol  
 Co-Chair: Poussot-Vassal, Charles ONERA

14:00-14:20 ThP1T1.1

*Linear Parameter Varying Techniques Applied to Aeroservoelastic Aircraft: In Memory of Gary Balas*, pp. 103-108

Pfifer, Harald Univ. of Minnesota

Moreno, Claudia P.	Univ. of Minnesota
Theis, Julian	Hamburg Univ. of Tech
Kotikalpudi, Aditya	Univ. of Minnesota
Gupta, Abhineet	Univ. of Minnesota
Takarics, Bela	Univ. of Minnesota
Seiler, Peter	Univ. of Minnesota

This paper presents an overview of Dr. Gary Balas research activities in linear, parameter-varying (LPV) systems applied to aeroservoelastic (ASE) aircraft. More efficient aircraft can be designed by reducing weight and structure in the wings and fuselage. This makes the aircraft more flexible leading to increased ASE effects. Such ASE aircraft can be modeled as a linear parameter varying (LPV) system with an arbitrary, i.e. not necessarily rational, dependence on the scheduling parameters. The system involves coupling of the aircraft structural dynamics and aerodynamics thus resulting in large state dimension. This large dimension necessitates special approaches to modeling, order reduction and control design. The paper describes the process of designing an LPV controller for flutter suppression of a flexible unmanned aircraft starting from the nonlinear equation of motions for the vehicle.

14:20-14:40 ThP1T1.2

*Rotorcraft Vibration Control: Adaptive vs LPV Methods*, pp. 109-114

Mura, Roberto	Pol. Di Milano
Lovera, Marco	Pol. Di Milano

This paper proposes a parameter-varying approach for the vibration control problem in rotorcraft applications. The proposed algorithm can be considered as a variant of Harmonic Control (HC), and can be placed beside existing adaptive versions used in the context of active controls design. In particular the novel approach accounts for the variation of the vibratory response of the rotorcraft structure (such as due to, eg, varying flight condition and actuator nonlinearities) directly in the synthesis of the control law. As a result, a robust parameter-varying controller, based on a discrete-time linear parameter varying model of the system, is obtained. Advantages and considerations on the effectiveness of the proposed approach are discussed by numerical examples, in comparison to other strategies well established in the literature.

14:40-15:00 ThP1T1.3

*LPV Modeling and LFT Uncertainty Identification for Robust Analysis: Application to the VEGA Launcher During Atmospheric Phase*, pp. 115-120

Marcos, Andres	Univ. of Bristol
Bennani, Samir	European Space Agency
Roux, Christophe	ELV
valli, monica	ELV

In this article, the development of a proper Linear Fractional Transformation model for the robust analysis of the atmospheric controllers of the European VEGA launcher is presented. By proper it is meant a model that: (i) captures the key launcher's behavior during the ascent atmospheric phase, (ii) has a complexity in terms of number of parameters and repetitions that does not limit the applicability of robust analyses, (iii) can be easily updated with very different trajectory profiles, and (iv) arises from a methodology that is well connected with industrial practice and can be understood and used relatively easy. This last requirement is fundamental to transfer the LFT methodology into the VEGA program, which is critical if robust analysis is to be used within their verification and validation process. The potential of the proposed methodology and the validity of the developed LFT models for robust analysis have been successfully verified using simulation data from three of the four VEGA qualification flights.

15:00-15:20 ThP1T1.4

*LPV Model Identification for Flutter Prediction: A Comparison of Methods*, pp. 121-126

Visser, Mart	Delft Univ. of Tech
Navalkar, Sachin	Delft Univ. of Tech

van Wingerden, Jan-Willem	Delft Univ. of Tech
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This paper compares four LPV identification methods, consisting of local, global, and glocal methods, for the application of flutter prediction and modeling. Important properties of the methods are highlighted and simulations are performed to compare the performance, using a bending-torsion flutter model from literature. Results show that a trade-off between bias and variance takes place for the local and global method, after which a glocal method can be used to further improve the bias and variance.

15:20-15:40 ThP1T1.5

*LPV Control for Multi-Harmonic Microvibration Attenuation: Application to High Stability Space Missions*, pp. 127-132

Preda, Valentin	Univ. of Bordeaux
Cieslak, Jérôme	Univ. of Bordeaux
Henry, David	Univ. of Bordeaux
Bennani, Samir	European Space Agency
Falcoz, Alexandre	EADS Astrium

This paper presents a LPV (Linear Parameter Varying) solution for the active part of a mixed passive-active control architecture to mitigate the microvibrations generated by reaction wheels in satellites. Hinf/LPV theory is used to mitigate low frequency disturbances. The issue of multiple harmonic microvibrations is also investigated. The results are evaluated using Hinf criteria and simulation results from a test benchmark provided by Airbus Defence and Space demonstrate the potential of the proposed method.

15:40-16:00 ThP1T1.6

*Parametric Reduced Order Dynamical Model Construction of a Fluid Flow Control Problem*, pp. 133-138

Poussot-Vassal, Charles	ONERA
Sipp, Denis	ONERA

The problem of approximating a given fluid flow control problem, governed by the Navier-Stokes equations at varying Reynolds number, with a low-order parametric linear dynamical model, is presented. To this aim, a three steps approach is proposed: first, (i) the original Reynolds number dependent fluid flow problem is spatially and parametrically discretized, then (ii) each resulting local very large-scale Linear Time Invariant (LTI) Differential Algebraic Equations (DAE) models are approximated using the IRKA approach proposed by Gugercin et al. (2008), and finally (iii), the reduced order models are interpolated and transformed into a low-complexity Linear Fractional Representation (LFR). The overall process is illustrated in a top down framework using a generic flow configuration, namely, an open cavity flow. Numerical simulations assess the validity of the approach.

ThP2T1 MJK

**CONTROL METHODS 2 (Regular Session)**

Chair: Guelton, Kevin	Univ. De Reims Champagne-Ardenne
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Co-Chair: Formentin, Simone	Pol. Di Milano
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16:30-16:50 ThP2T1.1

*LPVTools: A Toolbox for Modeling, Analysis, and Synthesis of Parameter Varying Control Systems*, pp. 139-145

Hjartarson, Arnar	MUSYN Inc
Seiler, Peter	Univ. of Minnesota
Packard, Andrew K.	Univ. of California at Berkeley

This paper describes the LPVTools software suite developed by MUSYN Inc. LPVTools is a MATLAB toolbox for simulation, analysis, and design of parameter dependent control systems using the Linear Parameter-Varying (LPV) framework. LPVTools contains data structures to represent both LFT and gridded (Jacobian-linearization) types of LPV systems. In addition it contains a collection of functions and tools for model reduction, analysis, synthesis and simulation of LPV systems. Finally, the



toolbox is fully documented and contains several demonstration examples. The software is freely available for use by the community.

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16:50-17:10 ThP2T1.2

*Nonparametric LPV Data-Driven Control*, pp. 146-151

Formentin, Simone	Pol. Di Milano
Piga, Dario	IMT Inst. for Advanced Studies Lucca
Tóth, Roland	Eindhoven Univ. of Tech
Savaresi, Sergio	Pol. Di Milano

In this paper, a data-driven technique for linear parameter-varying (LPV) controller design is discussed. The proposed method allows to synthesize directly from data an LPV controller in input-output (IO) form, without the need to identifying a model of the plant. In the state of the art methods, the controller structure must be given a-priori. Instead, in the proposed approach both the controller structure and parameters are automatically determined based on a set of experimental measurements. The effectiveness of the method is demonstrated on a numerical example.

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17:10-17:30 ThP2T1.3

*Generalized Dynamic Observers for LPV Singular Systems*, pp. 152-157

Osorio Gordillo, Gloria Lilia	CRAN, Univ. De Lorraine
Darouach, Mohamed	CRAN, Univ. De Lorraine
Boutat-Baddas, Latifa	CRAN, Univ. De Lorraine
Astorga Zaragoza, Carlos Manuel	Centro Nacional De Investigación Y Desarrollo Tecnológico

This paper presents a simple method to synthesize an observer for linear parameter varying (LPV) singular systems, based on a new observer structure named generalized dynamic observer (GDO) for singular systems. The conditions for the existence and stability of the GDO are given in a set of linear matrix inequalities (LMIs). The demonstration of the stability is done through Lyapunov analysis. A numerical example is given to show the present approach.

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17:30-17:50 ThP2T1.4

*A Networked-Based MPC Architecture for Constrained LPV Systems*, pp. 158-163

Casavola, Alessandro	Univ. Della Calabria
Lucia, Walter	Univ. Della Calabria
Tedesco, Francesco	Univ. Della Calabria

Regulation problems for networked constrained polytopic Linear Parameter Varying (LPV) systems are considered. It is assumed that the communication network is subject to latency effects which result in induced time-varying time-delays on both the control and measurement channels. A novel LPV customization of a recent Receding-Horizon control (RHC) scheme developed for polytopic uncertain linear systems is here proposed. It exploits the LPV scheduling parameter availability for pre-computing nested families of one-step ahead controllable ellipsoidal sets, which are significantly less conservative than their robust counterparts. Finally, simulation results concerning the constrained regulation of a unicycle-type mobile robot are reported to show the effectiveness and the benefits of the proposed control scheme.

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17:50-18:10 ThP2T1.5

*Quadratic Design of D-Stabilizing Non-PDC Controllers for Quasi-LPV/T-S Models*, pp. 164-169

Cherifi, Abdelmadjid	CReSTIC, Univ. De Reims Champagne-Ardenne
Guelton, Kevin	CReSTIC, Univ. De Reims Champagne-Ardenne
Arcese, Laurent	CReSTIC, Univ. De Reims Champagne-Ardenne

This paper deals with the D-stabilization of quasi-LPV/Takagi-Sugeno (TS) models. Based on a Quadratic Lyapunov Function

(QLF) candidate, basic conditions are presented for the design of D-stabilizing Parallel Distributed Compensation (PDC) control, i.e with LMI region constraints. Then, relaxed quadratic LMI conditions are proposed in order to design a D-stabilizing non-PDC controller. The proposed results are illustrated in simulation through an academic example, then through the benchmark of the stabilization of a flexible robot with single joint.

Technical Program for Friday October 9, 2015

<b>FrA1T1</b>	MJK
<b>FDI / FTC (Regular Session)</b>	

Chair: Theilliol, Didier Univ. of Lorraine  
 Co-Chair: Martinez Molina, Grenoble-INP, GIPSA-Lab  
 John J.

08:20-08:40 FrA1T1.1

*Null-Space Computation for qLPV Systems*, pp. 170-175

Szabo, Zoltan MTA-SZTAKI  
 Peni, Tamas MTA-SZTAKI  
 Bokor, Jozsef MTA-SZTAKI

Computation of the nullspace of a quasi linear parameter varying system (qLPV) bears significant importance in several fields of control theory, such as fault detection design or reconfigurable control design. While for linear time invariant systems computation of the stable nullspaces can be efficiently handled based on matrix pencil techniques, for more general cases, such as qLPV systems, such algorithms are not available. The paper provides a general scheme for the construction of the stable nullspaces that can be followed not only for dynamic (LTI, LTV, qLPV) systems but also in the case of memoryless, parameter varying matrices. The reliability of the proposed method for practical computations is also discussed. The algorithm is illustrated through small examples.

08:40-09:00 FrA1T1.2

*Robust Sensor Fault Detection and Isolation of an Anaerobic Bioreactor Modeled As a Descriptor-LPV System*, pp. 176-181

Lopez-Estrada, Tecnológico Nacional De  
 Francisco-Ronay Mexico. Inst. Tec De Tuxtla  
 Castañon-Gonzalez, José Inst. Tec. De Tuxtla Gutierrez  
 Humberto  
 Ponsart, Jean-Christophe CRAN, Univ. De Lorraine  
 Theilliol, Didier CRAN, Univ. De Lorraine  
 Astorga Zaragoza, Carlos Centro Nacional De  
 Manuel Investigación Y Desarrollo  
 Tecnológico

This work is dedicated to the design of a robust fault detection system for an anaerobic bioreactor modeled as a Descriptor Linear Parameter Varying system (D-LPV) system with unmeasurable gain scheduling functions. The main goals are: first, an accurate D-LPV representation of the nonlinear model is obtained by considering the sector nonlinearity modeling approach. Second, a LPV observer is designed to estimate the bioprocess states variables. The observer considers the gains scheduling functions depending on estimated states due to the lack of a biomass mass sensor. Third, in order to perform fault detection and isolation, by mean of residual generation, a bank of observers is designed. For each observer, sufficient conditions to guarantee asymptotic stability and robustness against disturbance are given by a set of feasible Linear Matrix Inequalities (LMIs). Finally, some simulations in fault-free and faulty operations are considered on the bioreactor system.

09:00-09:20 FrA1T1.3

*Minimal RPI Sets Computation for Polytopic Systems Using the Bounded-Real Lemma and a New Shrinking Procedure*, pp. 182-187

Martinez Molina, John J. Grenoble-INP, GIPSA-Lab

This paper deals with the problem of computing the minimal robustly positive invariant-sets (mRPI sets) for discrete-time linear and polytopic systems. Here, the subsystems, which describe a polytopic system, are assumed to be stable in presence of bounded disturbances and, in addition, to share a common Lyapunov function. The proposed approach is based on the computation of "ellipsoidal" RPI sets which are obtained by using the Bounded-real lemma. After that, a RPI outer-approximation of the minimal "polyhedral" RPI set for the polytopic system is obtained by applying a novel shrinking process. A shrinking index,

which depends on the number of iterations, is proposed as an indicator of the approximation error. Thus, the method provides mRPI set approximations that are always invariant sets at any step of the algorithm, and allows the a priori choice of a desired precision. Two numerical examples illustrate the application of a such method.

09:20-09:40 FrA1T1.4

*Fault Detection for LPV Systems: Loop Shaping H-Approach*, pp. 188-193

Farhat, Ahmad Univ. Grenoble Alpes  
 Koenig, Damien Grenoble-INP, GIPSA-Lab  
 Sename, Olivier Grenoble-INP, GIPSA-Lab

This paper addresses a method for fault detection (FD) in linear parameters varying (LPV) systems by maximizing the fault to residual sensitivity. It uses the newly developed H- index properties and minimizing the well known  $H_\infty$  norm for worst case uncertainties and disturbance attenuation. A loop shaping approach for the H- FD problem is proposed.

These multi-objectives are formulated as linear matrix inequality (LMI) feasibility problem in which an optimization criterion is minimized/maximized subject to LMI constraints at each polytope vertex. An application on lateral vehicle dynamics is given as an example for this approach.

09:40-10:00 FrA1T1.5

*A Switched LPV Observer for Actuator Fault Estimation*, pp. 194-199

Nguyen, Manh Quan Univ. Grenoble Alpes,  
 GIPSA-Lab  
 Sename, Olivier Grenoble-INP, GIPSA-Lab  
 Dugard, Luc GIPSA-Lab, CNRS Grenoble

In this paper, an actuator fault estimation problem is tackled, based on the LPV approach. First, the actuator fault is modeled in the form of a multiplicative fault by using a constant coefficient representing the loss of efficiency of the actuator's power  $\alpha$ . Therefore, the estimation of a time varying faulty actuator can be transformed into the estimation of a constant coefficient  $\alpha$ . Then, the faulty system is rewritten in the form of a switched LPV system. The coefficient  $\alpha$  and the system states are estimated using an extended switched observer. The stability and performance of the observer is ensured considering a switched time-dependent Lyapunov function. The observer gains are derived based on LMI solutions for polytopic switched systems. Some simulation results are presented that show the effectiveness of this approach.

<b>FrA2T1</b>	MJK
<b>APPLICATIONS (Regular Session)</b>	

Chair: Zasadzinski, Michel CRAN, Univ. De Lorraine  
 Co-Chair: Karimi, Alireza Ec. Pol. Fédérale De Lausanne

10:30-10:50 FrA2T1.1

*Linear Parameter-Varying Control of a Copolymerization Reactor*, pp. 200-206

Abbas, Hossameldin Assiut Univ  
 Mahmoud Seddik  
 Rahme, Sandy Qatar Univ  
 Meskin, Nader Qatar Univ  
 Hoffmann, Christian Hamburg Univ. of Tech  
 Tóth, Roland Eindhoven Univ. of Tech  
 Mohammadpour, Javad Univ. of Georgia

This paper demonstrates the application of the linear parameter-varying (LPV) framework to control a copolymerization reactor. An LPV model representation is first developed for a nonlinear model of the process. The LPV model complexity in terms of the model order and the number of scheduling variables is then reduced by truncating those system states that have insignificant direct influence on the input-output behavior of the

system and do not directly appear in the output equations of the model. It is important to note that these truncated states are still preserved in the reduced model by affecting the scheduling parameters and hence enabling the representation of the input-output map. Using the derived model, a linear fractional transformation (LFT) based LPV controller synthesis approach is used to synthesize a controller for the process. Simulation based studies of the closed-loop behavior of the system regulated by the designed LPV controller demonstrate that the LPV controller solution outperforms a model predictive control designed previously for this system in terms of the achieved control performance and the online computational effort.

10:50-11:10 FrA2T1.2

*Iterative Feedback Tuning of an LPV Feedforward Controller for Wind Turbine Load Alleviation*, pp. 207-212

Navalkar, Sachin Delft Univ. of Tech  
van Wingerden, Jan-Willem Delft Univ. of Tech

Modern wind turbines incorporate active control techniques such as Individual Pitch Control (IPC) to reduce lifetime dynamic loads. However, system identification and controller design are typically difficult for turbine load control on account of the LPV nature of the system and disturbance. This challenge is addressed by extending the data-based Iterative Feedback Tuning (IFT) technique to systems with LPV output matrices, controlled with a parameterised feedforward controller LPV in output matrices. In order to compensate for the parameter-varying nature of the plant, controller and disturbance, and to estimate the IFT cost gradients in an unbiased manner, an increased number of experiments is required. Such an LPV controller, tuned and tested in a high-fidelity simulation environment, is able to show enhanced load reductions as compared to an LTI controller.

11:10-11:30 FrA2T1.3

*An H-Infinity LPV Control for a Class of LPV Systems Using a Descriptor Approach. Application to a Wind Turbine Model*, pp. 213-217

Souley Ali, Harouna CRAN, Univ. De Lorraine  
Darouach, Mohamed CRAN, Univ. De Lorraine  
Zasadzinski, Michel CRAN, Univ. De Lorraine  
Alma, Marouane CRAN, Univ. De Lorraine

This paper is devoted to the synthesis of an H-infinity LPV state feedback controller, applied to a wind turbine which is described by an LPV model. Firstly, we focus on the modeling of wind turbines, to propose a model that describes as good as possible the system behaviour. A new approach that allows us, via LMI's, to design an LPV controller for a class of LPV systems is then presented. The interest of the approach is to decouple the system dynamic matrix and the Lyapunov one using a descriptor approach. Finally, to illustrate the proposed control strategy, some simulation results are presented.

11:30-11:50 FrA2T1.4

*Decentralized Robust Control of Power Grids Using LPV-Models of DAE-Systems*, pp. 218-223

Schaab, Konstantin Univ. of Kassel  
Stursberg, Olaf Univ. of Kassel

For large, distributed, and decentrally controlled systems, physical links between subsystems must be considered in designing local controllers to obtain global system stabilization. This manuscript addresses the task of robustly stabilizing systems with nonlinear subsystem dynamics and interconnections given by nonlinear algebraic equations, as motivated by the typical structure of power grids. The proposed approach first transforms the subsystems into a set of LPV-models, and the interconnections are represented by parameter intervals. For each subsystem, a local robustly stabilizing controller is synthesized by solution of a semidefinite program, and the stability of the overall system is implied if interval conditions for the parameters are satisfied. The method is demonstrated for a simple (yet often used) instance of a power grid.

11:50-12:10 FrA2T1.5

*Switching Robust Controllers for Automatic Regulation of Postoperative Hypertension Using Vasodilator Drug Infusion Rate*, pp. 224-229

Ahmed, Saeed Bilkent Univ  
Ozbay, Hitay Bilkent Univ

This paper proposes a new switching robust control algorithm, employing a stable hysteresis switching between neighboring controllers within a set of robust controllers designed for five different operating ranges of the system, for regulating the mean arterial blood pressure (MAP) in postsurgical scenario using infusion of vasodilator drug—Sodium Nitroprusside (SNP). Postoperative hypertension is very critical in patients with cardiac disorder and if it is left untreated, it may lead to adverse consequences. Since the sensitivity to the drug, injection delay and drug fraction recirculating vary among individuals, a robust control algorithm becomes an attractive candidate for regulating MAP in the presence of such parameter uncertainties. In addition, the sensitivity to the drug may even vary with time within the same patient, therefore, it is also treated in the model as time-varying value of the parameter. A stable hysteresis switching between neighboring robust controllers is proposed for larger operating range of the system due to considerably large uncertainty range of the patients' sensitivity to the drug.

12:10-12:30 FrA2T1.6

*Fixed-Order Linear Parameter Varying Controller Design for a 2DOF Gyroscope*, pp. 230-235

Emedi, Zlatko Etel Sa  
Karimi, Alireza Ec. Pol. Fédérale De Lausanne

This paper presents an approach for fixed-order Linear Parameter Varying (LPV) controller design with application to a 2 Degree-of-Freedom (2DOF) gyroscope experimental setup. Inner convex approximation of the non-convex set of all stabilizing fixed-order LPV controllers is characterized through a set of Linear Matrix Inequalities (LMIs). This is achieved through the use of two slack matrices which enable decoupling of the controller and Lyapunov matrix parameters in the derivative of Lyapunov function. The LPV model obtained by the approximation of the nonlinear model of the 2DOF gyroscope is used for the design of a second-order LPV controller. Experimental results show good tracking performance in the presence of scheduling parameter variations.

12:30-12:50 FrA2T1.7

*Design and Experimental Tests of an LPV Power System Stabilizer on a 10kVA Small-Scale Generating Unit*, pp. 236-241

Nogueira, Fabrício Gonzalez Univ. Federal Do Ceará  
Barra Jr., Walter Univ. Federal Do Pará  
Da Costa Jr., Carlos Univ. Federal Do Pará  
Barreiros, José Univ. Federal Do Pará  
De Lana, Janio Centrais Elétricas Do Norte Do Brasil

In this paper, the application of linear parameter-varying (LPV) identification and control methods for designing and performance evaluation of an adaptive power system stabilizer (PSS) is presented. The target control objective is to improve the damping of the dominant electromechanical oscillating mode in the power system. The performance of the LPV PSS controller has been assessed by means of experimental tests carried out on 10 kVA small-scale power system. For design purposes, a LPV ARX model was estimated from experimental tests, for a wide range of operating conditions. The LPV controller was tuned via an optimization problem, in the form of a Parameterized Linear Matrix Inequality (PLMI). The solution was obtained through a sum-of-squares relaxation. Both the LPV model and the LPV-PSS have an explicit dependency on system scheduling variables, namely the active and reactive powers measurements. Therefore, the LPV-PSS was designed to ensure stability and performance for a wide range of operating conditions, an objective usually difficult to obtain by using fixed parameter controllers.

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Nonlinear Systems	FrA2T1.1, ThAT1.1, ThAT1.2, ThAT1.3, WeAT1.3, WePT1.7
O	
Observer Design	ThP2T1.3, WeAT1.6, WePT1.1, WePT1.7
Optimal Control	FrA2T1.2, WeAT1.5, WePT1.2, WePT1.5
P	
Polynomial Systems	FrA2T1.7
R	
Robotics	FrA2T1.6, ThAT1.1
Robustness Issues	FrA1T1.3, ThP1T1.2, ThP1T1.3, ThP1T1.5, ThP2T1.4, ThPlenary2T1.1, WeAT1.6, WePlenary1T1.1
S	
Sampled-Data Systems	ThAT1.4, ThP1T1.4, WeAT1.4
Stability and Stabilization	FrA1T1.1, FrA2T1.3, FrA2T1.4, FrA2T1.6, FrA2T1.7, ThP2T1.5, ThPlenary2T1.1, WeAT1.1, WeAT1.2, WeAT1.3, WeAT1.4, WeAT1.5, WeAT1.6, WePlenary1T1.1, WePT1.3
Structural Analysis	ThP1T1.6
Switching Systems	FrA1T1.5, FrA2T1.5, WePT1.2
T	
Time-Delay Systems	FrA2T1.5, ThP2T1.4
U	
Uncertain Systems	FrA1T1.3, ThP1T1.2, ThP1T1.3, ThP1T1.4, ThP1T1.6, ThP2T1.2, ThP2T1.3, WeAT1.1
V	
Virtual Reference Feedback Tuning	ThP2T1.2