



Proceedings of SOMC 2012, Self-Organisation Management and Control, a satellite meeting within ECCS'12

Moulay-Ahmed Aziz-Alaoui, Arnaud Banos, Cyrille Bertelle, Gérard H.E.
Duchamp

► To cite this version:

Moulay-Ahmed Aziz-Alaoui, Arnaud Banos, Cyrille Bertelle, Gérard H.E. Duchamp (Dir.). Proceedings of SOMC 2012, Self-Organisation Management and Control, a satellite meeting within ECCS'12. 37 p., 2012. hal-03317887

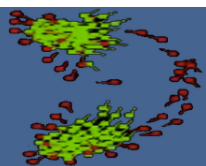
HAL Id: hal-03317887

<https://hal.science/hal-03317887>

Submitted on 8 Aug 2021

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.



SOMC'2012 within ECCS'12 Self-Organization, Management and Control



SOMC 2012

Self-Organization, Management and Control

A Satellite Meeting of

ECCS'12

European Conference on Complex Systems

September 6th, 2012

Brussels, Belgium

Editors

M. Aziz-Alaoui

Arnaud Banos

Cyrille Bertelle

Gérard H.E. Duchamp

ECCS '12
European Conference on Complex Systems

Brussels



SOMC 2012

**Self-Organization, Management
and Control**

**A Satellite Meeting of
ECCS'12
European Conference on
Complex Systems**

**September 6th, 2012
Brussels, Belgium**

Editors

**M. Aziz-Alaoui, Arnaud Banos,
Cyrille Bertelle and Gérard H.E. Duchamp**

Program Committee:

- Abdulrab, Habib, ISCN & INSA Rouen, France
- Ayesh, Aladdin, ISCN & De Montfort University, U.K.
- Aziz-Alaoui, M.A., ISCN & University of Le Havre, France
- Babkin, Edward, ISCN & Higher School of Economics (Nizhny Novgorod), Russia
- Badariotti Dominique, LIVE, Strasbourg, France
- Banos Arnaud, ISC-PIF & Géographie-cités UMR 8504, Paris, France
- Bertelle, Cyrille, ISCN & University of Le Havre, France
- Chen G., City University of Hong-Kong, China
- Duchamp, Gérard H.E., ISCN & Paris XIII University, France
- El Hami, Abderkhalak, ISCN & INSA Rouen, France
- Elissalde B., ISCN & University of Rouen, France
- Ghedira K., ISG & City of Sciences, Tunis, Tunisie
- Ghnemat, Rawan, ISCN & German-Jordanian University, Amman, Jordan
- Guinand, Frédéric, ISCN & University of Le Havre, France
- Gulyas, Laszlo, ISCN & Eotvos University, Budapest, Hungary
- Iantovics, Barna L., ISCN & Petru Maior University of Tg. Mures, Romania
- Latapi Matthieu, LIP6, Paris France
- Li B.-L., California University, USA
- Lozi R., Nice University, France
- Lu Jinhu, Chinese Academy of Sciences, China
- Lucchini Françoise, ISCN & University of Rouen, France
- Mélançon Guy, Labri, Bordeaux France
- Olivier, Damien, ISCN & University of Le Havre, France
- Perna Andréa, ISC-PIF, Paris France
- Provitolo Damienne, Géosciences Azur, Sophia Antipolis France
- Rozenblat Céline, University of Lausanne, Switzerland
- Rouquier Jean-Baptiste, ISC-PIF, Paris France
- Sanjuan Miguel A.F., University Rey Juan Carlos, Madrid, Spain

General Chairs:

- **M. Aziz-Alaoui**, ISCN & LMAH, University of Le Havre
25 Rue Ph. Lebon, BP 540, 76058 Le Havre Cedex, France.
Phone: +33 235 217 213
email: aziz.alaoui@univ-lehavre.fr
- **Arnaud Banos**, ISC-PIF & Géographie-cités, CNRS
13 rue du Four, 75006 Paris, France.
Phone: +33 140 464 000
email: arnaud.banos@parisgeo.cnrs.fr
- **Cyrille Bertelle**, ISCN & LITIS, University of Le Havre
25 Rue Ph. Lebon, BP 540, 76058 Le Havre Cedex, France.
Phone: +33 235 217 214
email: cyrille.bertelle@univ-lehavre.fr
- **Gérard H.E. Duchamp**, ISCN & LIPN, University of Paris 13
99 avenue Jean-Baptiste Clément, 93400 Villetaneuse, France.
Phone: +33 149 402 862
email: ghed@lipn.univ-paris13.fr

This Satellite Meeting is organized under the auspices of:

- ISCN, Institute of Complex Systems in Normandy, France
<http://isc-n.fr>
- ISC-PIF, Complex Systems Institute, Paris-île de France, France
<http://iscpif.fr>
- S4, European Research Group “Spatial Simulation for Social Systems”
<http://s4.parisgeo.cnrs.fr/>
- RNSC, French Network of Complex Systems
<http://rnsc.fr>

The organizers thank for their scientific and financial supports:

- LITIS, Laboratory of Computer Science, Information Processing and Systems, University of Le Havre, University of Rouen & Insa Rouen, France
<http://www.litislabs.eu>
- LMAH, Laboratory of Applied Mathematics, University of Le Havre, France
<http://lmah.univ-lehavre.fr>
- LIPN, Laboratory of Computer Science, Paris Nord, France
<http://www-lipn.univ-paris13.fr/>
- Géographie-cités, Paris, France
<http://www.parisgeo.cnrs.fr/>
- University of Le Havre, France
<http://www.univ-lehavre.fr>
- University of Paris 13, France
<http://www.univ-paris13.fr>
- CNRS, France
<http://www.cnrs.fr>
- MESR, Ministry of Higher Education and Research, France
<http://www.enseignementsup-recherche.gouv.fr/>
- Région Haute-Normandie, France
<http://www.hautenormandie.fr/>
- Région Paris-île de France
<http://www.iledefrance.fr/>
- European Regional Development Fund
<http://www.europe-haute-normandie.fr>
- Nov@log Pole of Competitiveness
<http://www.novalog.eu>

Preface

Complex Systems have to face with their own interacting entities within an environment or a context. The specificity of this satellite meeting is to show how collective behaviors or emergent properties can arise within these systems through their structures and through their dynamics. In this meeting, we consider that control and self-organization are not antagonist and that complexity is typically expressed inside systems mixing these two concepts; each of them feeds back on the other, using nonlinear processes. Modeling these feedbacks and identifying the multiple two-way links between (i) self-organization and control (ii) dynamical morphology of the system and (iii) evolution of the system, is in the core of our focus. “Does morphology control system dynamics and if so, how modeling this kind of control?” is an example of question involved in this meeting. These aspects in complex systems are transversal within a great number of various applications covering natural and artificial phenomena at various scales (ecosystems, biological systems, urban systems, logistics, economy, social systems, languages development, cognitive systems, brain dynamics).

Le Havre & Paris
August 22th 2012

M. Aziz-Alaoui
Arnaud Banos
Cyrille Bertelle
G rard H.E. Duchamp

Contents

Preface	vii
Contents	ix
I Invited and selected contributions	1
Passification Based Controlles Synchronization of Complex Networks	
A.L. FRADKOV, I.A. JUNUSOV and A.A. SELIVANOV	3
Topology Identification and Cluster Synchronization in Complex Dynamical Networks	
M.A. AZIZ-ALAOUI, J. ZHAO, and C. BERTELLE	5
Coupled HR neurons: on the influence of the coupling strength on the neuron dynamics	
S. BALEV and N. CORSON	9
Improving Individual Accessibility to the City: an Agent Based Modelling Approach	
N. MARILLEAU and MIRO TEAM	13
Co-evolution of the Road Network and the Land Use in a City	
M. ACHIBET, S. BALEV, A. DUTOT and D. OLIVIER	15
Complex Systems in Education: International Study of Multidisciplinary Interactions for Promoting the Learning of Mathematics and Science	
R. LOZI and N. BIAGOLI	17
Searching Shortest Paths in Weakly Graph	
J.Y. COLIN, M. NAKECHBANDI and A.S. OULD CHEIKH	29
II Practical session/tutorial	31
GraphStream, a Java Library for Dynamical Complex Networks	
Eric DEUSSÉ	33
Index	37

Part I

Invited and selected contributions

PASSIFICATION BASED CONTROLLED SYNCHRONIZATION OF COMPLEX NETWORKS

Alexander L. Fradkov, Ibragim A. Junussov and Anton A.Selivanov *

Abstract. In the paper an output synchronization problem for networks of linear dynamical agents is examined based on passification method and recent results in graph theory. The static output feedback and adaptive control are proposed and sufficient conditions for synchronization are established ensuring synchronization of agents under incomplete measurements and incomplete control. The results are extended to the networks with sector bounded nonlinearities in the agent dynamics and information delays.

Keywords. Complex Networks, Passification, Synchronization.

1 Introduction

Controlled synchronization of networks has a broad area of important applications: control of power networks, cooperative control of mobile robots, control of lattices, control of biochemical, ecological networks, etc.[1, 2, 3, 4, 5]. However most existing papers deal with control of the networks of dynamical systems (agents) with full state measurements and full control (vectors of agent input, output and state have equal dimensions). In the case of synchronization by output feedback additional dynamical systems (observers) are incorporated into network controllers.

In this paper the synchronization problem for networks of linear agents with arbitrary numbers of inputs, outputs and states by static output neighbor-based feedback is solved based on passification method [6, 7] and recent results in graphs theory. The results are extended to the networks with sector bounded nonlinearities in the agent dynamics and information delays.

2 Problem statement

Let the network S , consist of d agents $S_i, i = 1, \dots, d$. Each agent S_i is modeled as a controlled system

$$\dot{x}_i = Ax_i + B_0 f(x_i) + Bu_i, \quad y_i = C^T x_i, \quad (1)$$

*Alexander L. Fradkov is with Institute for Problems of Mechanical Engineering and St.Petersburg State University, Russia. E-mail: fradkov@mail.ru. Ibragim A. Junussov and Anton A.Selivanov are with St.Petersburg State University, St.Petersburg, Russia. E-mails: dxttdfxut@gmail.com, antonselivanov@gmail.com

where $x_i \in \mathbb{R}^n$ is state vector, $u_i \in \mathbb{R}^1$ is controlling input (control), $y_i \in \mathbb{R}^l$ is the vector of measurements (output). Let $\mathcal{G} = (\mathcal{V}, \mathcal{E})$, be the digraph with the set of vertices \mathcal{V} and the set of arcs $\mathcal{E} \subseteq \mathcal{V} \times \mathcal{V}$, such that for $i = 1, \dots, d$ the vertex v_i is associated with the agent S_i and the arc (v_i, v_j) belongs to the set of arcs \mathcal{E} if the information comes from the agent S_j to the agent S_i . Digraph G is called communication graph of the network. The case when the graph G is undirected (communication channels are undirected) will be considered too.

Let the control goal be:

$$\lim_{t \rightarrow \infty} (x_i(t) - x_j(t)) = 0, i, j = 1, \dots, d. \quad (2)$$

3 Static control

Let control law for S_i be

$$u_i(t) = K \sum_{j \in \mathcal{N}_i} (y_i(t - \tau) - y_j(t - \tau)) = KC^T \sum_{j \in \mathcal{N}_i} (x_i(t - \tau) - x_j(t - \tau)), \quad (3)$$

$$K \in \mathbb{R}^{1 \times l},$$

where $\mathcal{N}_i = \{k = 1, \dots, d | (v_i, v_k) \in \mathcal{E}\}$ is the set of neighbor vertices to v_i , $\tau \geq 0$ is communication delay.

The problem is to find K from (3) such that the goal (2) holds.

The problem is first analyzed for linear agent dynamics ($B_0 = 0$) without delays ($\tau = 0$) under the following assumptions:

A1) $B \neq 0, (\text{rank} B = 1)$ and there exists a vector $g \in \mathbb{R}^l$ such that the function $g^T W(s)$ is hyper-minimum-phase, where $W(s) = C^T(sI - A)^{-1}B$.

Recall that the rational function $\chi(s) = \beta(s)/\alpha(s)$ is called *hyper minimum phase*, if its numerator $\beta(s)$ is a Hurwitz polynomial and its highest coefficient β_{n-1} is positive. Hyper minimum phase property is necessary and sufficient for existence a linear output feedback rendering the closed loop system passive [7].

A2) The communication graph is undirected and connected.

A2D) The communication graph is directed and has the directed spanning tree.

Let $A(\mathcal{G})$ denote adjacency matrix of the graph \mathcal{G} . For digraph \mathcal{G} consider the graph $\hat{\mathcal{G}}$ $A(\hat{\mathcal{G}}) = A(\mathcal{G}) + A(\mathcal{G})^T$. Laplacian $L(\hat{\mathcal{G}}) = D(\hat{\mathcal{G}}) - A(\hat{\mathcal{G}})$ of the graph $\hat{\mathcal{G}}$ is symmetric and has the eigenvalues: $0 = \lambda_1 < \lambda_2 \leq \dots \leq \lambda_d$, [1, 3]. The main result is as follows.

Theorem 1. Let $B_0 = 0$, $\tau = 0$, assumptions A1 and either A2 or A2D hold and $k \geq 2\kappa/\lambda_2$, where

$$\kappa = \inf_{\omega \in \mathbb{R}^1} \operatorname{Re}(g^T W(i\omega)). \quad (4)$$

Then the control law (3) with feedback gain $K = -kg^T$, $k \in \mathbb{R}^1$ ensures the goal (2).

It is also shown that Theorem 1 holds if the communication delay $\tau > 0$ is sufficiently small. Similar results are obtained for $B_0 \neq 0$ and sector bounded nonlinearities $f(x_i)$, if $B_0 = B$ or B_0 is sufficiently small.

4 Adaptive control

Let agent S_i be able to adjust its control gain, i.e. each local controller is adaptive. Let each controller have the following form:

$$u_i(t) = \theta_i(t)y_i(t), \quad (5)$$

where $\theta_i(t) \in \mathbb{R}^{1 \times 1}$ – tunable parameter which is tuned based on the measurements from the neighbors of i -th agent.

Denote:

$$\bar{y}_i = \sum_{j \in \mathcal{N}_i} (y_i - y_j), i = 1, \dots, N$$

and consider the following adaptation algorithm:

$$\begin{aligned} \dot{\theta}_i(t) &= -g^T \cdot k_i(t), \\ \dot{k}_i(t) &= y_i(t)^T g g^T \bar{y}_i. \end{aligned} \quad (6)$$

Adaptive synchronization conditions are formulated as follows.

Theorem 2. Let assumptions A1, A2 hold. Then adaptive controller (5) - (6) ensures achievement of the goal (2).

Adaptive control algorithm does not require knowledge of the network parameters to determine the value of the gain needed to achieve synchronization.

5 Conclusions

We propose the control algorithm for synchronization of networks based on static output feedback (3) to each agent from the neighbor agents. Since the number of inputs and outputs of the agents are less than the number of agent state variables, synchronization of agents is achieved under incomplete measurements and incomplete

control. Synchronization conditions include passifiability (hyper-minimum-phase property) for each agent and some connectivity conditions for communication graph: existence of the directed spanning tree in case of directed graph and connectivity in case of undirected graph. Similar conditions are obtained for adaptive passification-based control of network with undirected communication graph, for sector bounded nonlinearities in the agent dynamics and communication delays.

The proposed solution for output feedback synchronization unlike those of [4, 5] does not use observers. Compared to static output feedback result of [4] (Theorem 4) the proposed synchronization conditions relax passivity condition for agents to their passifiability that allows for unstable agents. The paper [4], however, deals with time-varying network topology. The presented results extend our previous results [8, 9, 10] to the networks with the communication delays.

The theoretical results are illustrated by the simulation results for the networks of double integrators and chaotic Chua circuits.

Acknowledgements

The work was supported by Russian Foundation for Basic Research (project 11-08-01218) and Russian Federal Program “Cadres” (contract 16.740.11.0042).

References

- [1] Olfati-Saber R., Murray R.M. “Consensus Problems in Networks of Agents With Switching Topology and Time-Delays,” *IEEE Trans. on Autom. Control*, 49(9):1520-1533, 2004.
- [2] Boccaletti S., Latora V., Moreno Y., Chavez M. and D. U. Hwang. “Complex networks: Structure and dynamics,” *Physics Reports-Review Section of Physics Letters*, 424(4-5):175-308, 2006.
- [3] Bullo F., Cortez J. and Martinez S. *Distributed control of robotic networks*, Princeton Univ. Press, 2009.
- [4] Scardovi L. and Sepulchre R. “Synchronization in networks of identical linear systems,” *Automatica*, 45(11):2557-2562, 2009.
- [5] Li Z., Duan Z., Chen G. and Huang L. “Consensus of multiagent systems and synchronization of complex networks: a unified viewpoint,” *IEEE Trans. Circ. Syst. I.*, 57(1): 213-224, 2010.
- [6] Fradkov A. L., Miroshnik I. V. and Nikiforov V. O. *Nonlinear and Adaptive Control of Complex Systems*, Dordrecht: Kluwer, 1999.
- [7] Fradkov A. L. “Passification of nonsquare linear systems and feedback Yakubovich-Kalman-Popov lemma,” *Eur. J. Control*, 6:573–582, 2003.
- [8] Fradkov A.L., Junussov I. “Output feedback synchronization for networks of linear agents” *7th European Nonlinear Dynamics Conference (ENOC 2011)*, Rome, 2011.
- [9] Dzhunusov I.A. and Fradkov A.L. “Synchronization in Networks of Linear Agents with Output Feedbacks,” *Automation and Remote Control*, Vol. 72, No. 8, pp. 1615-1626, 2011.
- [10] Fradkov A. L., Grigoriev G. K., Selivanov A. A. “Decentralized Adaptive Controller for Synchronization of Dynamical Networks with Delays and Bounded Disturbances,” *Proc. 50th IEEE Conf. Dec. Contr.* Orlando, pp.1110-1115, 2011.

TOPOLOGY IDENTIFICATION AND CLUSTER SYNCHRONIZATION IN COMPLEX DYNAMICAL NETWORKS

M.A. Aziz-Alaoui, J. Zhao and C. Bertelle, ^{*}[†]

Abstract.

Topology identification of networks has recently got high concern due to various properties of networks, such as cascade and robustness, which are determined by the structure of the network. Adaptive control has been proposed to estimate the unknown topology under a key condition: persistently exciting condition. However, when this condition is not satisfied, how to identify a network topology? In the first part of this talk, we show that noise induces topology identification when this condition is not satisfied. Meanwhile, the identification scheme is still effective for complex networks whose topology switches. In a second part of the talk, we deal with cluster synchronization which is an interesting issue in complex dynamical networks with community structure. We study cluster synchronization of complex networks with nonidentical systems by input-to-state stability. Some sufficient conditions that ensure cluster synchronization of complex networks are provided. The increase of coupling strength inside clusters is very useful to achieve cluster synchronization, however, the coupling among clusters is an obstacle for cluster synchronization. The analysis is then extended to the case where the outer coupling strengths are adaptive. Finally, numerical simulations are given to validate our theoretical analysis.

Keywords. Complex system, networks, cluster, topology identification, synchronization.

1 Introduction

Nowadays, complex networks, such as transportation and phone networks, wireless networks, internet and the World Wide Web, play an important role in our life. Significant progress has been made in studying complex networks since the discovery of their small-world [25] and scale-free [26] characteristics. Recently, synchronization of complex networks has aroused broad interest. Two basic tools are used to analyze various synchronization problems of complex networks. The one is *master stability function*, which is proposed by Pecora and Carroll [27]. The other is *connection graph stability method*, which is given by Belykh *et al.* [28, 29].

However, the above conclusions are based on the condition that the topology of complex network is known.

When the topology is unknown, it is very important to estimate it in the study of complex networks. The topology identification (TI), as an inverse problem, has received more and more attention from the system science community. Many effective methods are used to study the identification problem from different fields [30]-[34], such as time series analysis, adaptive control, augmented optimization. Here, we focus on adaptive control to TI. The method is effective for the TI of complex network with identical chaotic systems. Considering the complex dynamical network with unknown topology as a drive system, some researchers built a response system and adaptive controls to estimate the unknown topology, and discovered that linearly independent condition on synchronization manifold is very important in the process of TI [31, 32]. However, the condition is difficult to validate especially on the synchronization manifold. In a previous work [33], we use persistently exciting (PE) condition to replace the above one. TI of complex network is successful when PE is satisfied, otherwise it can be failed. Additionally, the PE condition can be validated by numerical simulations.

Synchronization, as an interesting phenomenon of a population of dynamically interacting agents, has received wide attention from different fields [23, 27, 22, 7, 18, 24]. For example, recently an underwater photographer observed that a huge group of sardines, probably tens of thousands of them, was seen mimicking a dolphin in the sea off Philippines. Usually, the identical synchronization is considered as the complete coincidence of the states of individual systems. Other synchronization phenomena have been proposed, such as lag synchronization, phase synchronization, generalized synchronization [4, 3, 14].

In another hand, complex networks have got broad concern and make great progress in the past decade [25, 26]. Meanwhile, the results from the present investigation suggest that many networks have the community structure, especially in social and biological cases, many individuals maintain close contact with others in a same cluster, while only a few individuals link with an outside cluster. Hence, there is an emerging phenomenon that the individuals are synchronized inside the same cluster, but

^{*}Author1 and Author3 are with labs of Applied Mathematics and Computer science, University of LeHavre, Normandy, France. E-mails: aziz.alaoui@univ-lehavre.fr, cyrille.bertelle@gmail.com

[†]Author2 is with Research Center of Nonlinear Science (RCNS), Textile University of Wuhan, China. E-mail: junchanzhao@gmail.com

there is no synchronization among the clusters. The phenomenon has been called cluster synchronization, and, as a special synchronization on complex dynamical networks, it has got broad concern recently. Considering two-dimensional lattices of diffusively coupled identical chaotic oscillators, Belykh *et al* [6] concluded that such cluster synchronization regimes persist when the chaotic oscillators have slightly different parameters. Constructing a new coupling scheme with cooperative and competitive weight-couplings, Ma *et al* [20] investigated cluster synchronization patterns with several clusters for connected chaotic networks. Applying the connection graph stability method, Chen and Lu [13] obtained that complete synchronization within each cluster is possible only if each node from one cluster receives the same input from nodes in other cluster. Based on the transverse stability analysis, Lu *et al* [19] presented sufficient conditions for local cluster synchronization of networks.

2 Problem statement and preliminaries

In this paper, we only focus on the network cluster synchronization. For the first part, concerning the topology identification, see [1].

Let us assume that the network only has two clusters, that is, $N_{clus} = 2$. The individuals are identical in the same cluster, and non-identical otherwise. Consider the unweighted and undirected network of N linearly coupled oscillators:

$$\left\{ \begin{array}{l} \dot{x}_i = f(t, x_i) + \epsilon_1 \sum_{j=1, j \neq i}^M c_{ij}(x_j - x_i), \\ i = 1, \dots, M - k_1, \\ \dot{x}_i = f(t, x_i) + \epsilon_1 \sum_{j=1, j \neq i}^M c_{ij}(x_j - x_i) + \\ c_i(t) \sum_{j=M+1}^{M+k_2} c_{ij}(y_j - x_i), \\ i = M - k_1 + 1, \dots, M, \\ \dot{y}_i = g(t, y_i) + \epsilon_2 \sum_{j=M+1, j \neq i}^N c_{ij}(y_j - y_i) + \\ c_i(t) \sum_{j=M-k_1+1}^M c_{ij}(x_j - y_i), \\ i = M + 1, \dots, M + k_2, \\ \dot{y}_i = g(t, y_i) + \epsilon_2 \sum_{j=M+1, j \neq i}^N c_{ij}(y_j - y_i), \\ i = M + k_2 + 1, \dots, N. \end{array} \right. \quad (1)$$

where $x_i \in \mathbb{R}^m$ is the state variables of the first M nodes, $y_i \in \mathbb{R}^m$ is the state variables of the others, $f, g : \mathbb{R} \times \mathbb{R}^m \rightarrow \mathbb{R}^m$ are continuous functions; $\epsilon_i > 0$ are the inner coupling strength in a cluster, while c_i are the outer coupling strength between two clusters. k_1, k_2 are the number of nodes which connect to outside clusters. $C = (c_{ij})_{N \times N}$ is an adjacency matrix of the network, in which c_{ij} is one if there is a connection from node i to

node j ($i \neq j$), and is zero otherwise. Throughout the paper, $\|\cdot\|$ denotes the Euclidean norm for vectors and the Frobenius norm for matrices. I_n is the identity matrix of order n .

To begin with, for the convenience of the reader, we recall several necessary mathematical preliminaries.

Assumption 2.1. [38, 39, 40]: There exists a positive constant L , such that

$$(x - y)^T (\psi(t, x) - \psi(t, y) - \Delta(x - y)) \leq -L(x - y)^T (x - y),$$

for any $x, y \in \mathbb{R}^m$ and $t \geq t_0$. Here $\Delta = \text{diag}\{\delta_1, \dots, \delta_m\}$ is a diagonal matrix.

Remark 2.1. All linear and piecewise-linear continuous functions satisfy this condition. In addition, if a solution of an ODE system is bounded for any initial condition, the above condition is satisfied. Thus, it includes many well-known chaotic systems, such as the Rössler system [21], Lorenz system family [16, 12, 17].

Definition 2.1. The network (1) is said to achieve cluster synchronization if nodes in the same cluster are synchronized, i.e., for all nodes i, j in the same cluster, $\|x_i - x_j\| \rightarrow 0$ as $t \rightarrow \infty$. While if nodes i and j belong to different clusters, $\|x_i - y_j\| \not\rightarrow 0$ as $t \rightarrow \infty$.

Definition 2.2. A continuous function $\gamma : [0, a) \rightarrow [0, \infty)$ is said to be a class \mathcal{K} function if it is strictly increasing and $\gamma(0) = 0$. It is said to be a \mathcal{K}_∞ function if $a = \infty$ and $\gamma(t) \rightarrow \infty$ as $t \rightarrow \infty$. A continuous function $\beta : [0, a) \times [0, \infty) \rightarrow [0, \infty)$ is said to be a \mathcal{KL} function if, for each fixed s , $\beta(\cdot, s)$ is a class \mathcal{K} function, and for each fixed r , $\beta(r, s)$ is decreasing with respect to s and $\beta(r, s) \rightarrow 0$ as $s \rightarrow \infty$ ([15], Ch.3, pp.145).

Definition 2.3. [36] A function $\varphi : \mathbb{R}^+ \rightarrow \mathbb{R}^{n \times m}$ is persistently exciting (PE) if there exist $T_0, \tilde{\delta}_1, \tilde{\delta}_2 > 0$ such that,

$$\tilde{\delta}_1 I_n \leq \int_t^{t+T_0} \varphi(\tau) \varphi^T(\tau) d\tau \leq \tilde{\delta}_2 I_n, \quad (2)$$

holds for all $t \geq 0$.

Lemma 2.1. [37] Given a system of the following form:

$$\begin{cases} \dot{e}_1 = \beta_1(t) + \zeta(t)e_2; & e_1 \in \mathbb{R}^p \\ \dot{e}_2 = \beta_2(t) \end{cases} \quad (3)$$

such that,

(i) $\lim_{t \rightarrow \infty} \|e_1(t)\| = 0, \lim_{t \rightarrow \infty} \|\beta_1(t)\| = 0, \lim_{t \rightarrow \infty} \|\beta_2(t)\| = 0;$

(ii) $\zeta(t), \dot{\zeta}(t)$ are bounded, and $\zeta^T(t)$ is PE.

Then $\lim_{t \rightarrow \infty} \|e_2(t)\| = 0$.

3 Cluster synchronization by input-to-state stability

In the second equation of system (1), we regard the term $c_i(t) \sum_{j=M+1}^{M+k_2} c_{ij}(y_j - x_i)$ as an input perturbation $u_i(t)$ in the first cluster, and definite a coupling matrix

$$B = \begin{cases} b_{ij} = c_{ij}, & i \neq j, \quad i, j = 1, \dots, M, \\ b_{ii} = c_{ii} = - \sum_{j=1, j \neq i}^M c_{ij}, & i = 1, \dots, M. \end{cases} \quad (4)$$

Rewrite the first M systems as the following form:

$$\dot{x}_i = f(t, x_i) + \epsilon_1 \sum_{j=1}^M b_{ij} x_j + u_i, \quad i = 1, \dots, M. \quad (5)$$

Remark 3.1. In each cluster, the individuals keep in close contact with each other. It is reasonable to assume that each cluster is connected. Thus, the coupling matrix B of the first cluster is negative semi-definite. It has a simple eigenvalue zero and all the other eigenvalues are negative [11].

Then the cluster synchronization can be transferred to the synchronization of each cluster. We now discuss the problem of synchronization for the system (5). The average state trajectory of uncoupled systems is regarded as the synchronization trajectory [10]

$$s = \frac{1}{M} \sum_{j=1}^M x_j \quad (6)$$

and

$$\dot{s} = \frac{1}{M} \sum_{j=1}^M f(t, x_j) \quad (7)$$

Define error vectors as

$$e_i = x_i - s, \quad i = 1, \dots, M \quad (8)$$

and notice that the diffusive coupling condition

$$\sum_{j=1}^M b_{ij} = 0,$$

the error systems are thus described by

$$\dot{e}_i = f(t, x_i) - \frac{1}{M} \sum_{j=1}^M f(t, x_j) + \epsilon_1 \sum_{j=1}^M b_{ij} e_j + u_i, \quad i = 1, \dots, M. \quad (9)$$

Definition 3.1. The dynamical network (5) is said to achieve ISS if there exist a class \mathcal{KL} function β , and a class \mathcal{K} function γ such that for any $e(t_0)$ and bounded u ,

$$\|e(t)\| \leq \beta(\|e(t_0)\|, t - t_0) + \gamma \left(\sup_{t_0 \leq \tau \leq t} \|u(\tau)\| \right),$$

for all $t \geq t_0$, where $e^T = (e_1^T, \dots, e_M^T)$ and $u^T = (0, \dots, 0, u_{M+1-k}^T, \dots, u_M^T)$.

Our main result is given in the following theorem.

Theorem 3.1. *If the function f of Eq. (5) satisfies Assumption 2.1 and u_i are bounded, then the first cluster of network given by Eq. (5) is ISS for a sufficiently large coupling strength ϵ_1 .*

Proof. See [2].

4 Cluster synchronization by adaptive method

In this section, an adaptive law on the coupling strength $c_i(t)$ is proposed so that each cluster can achieve synchronization. The main result is the following, see [2].

Theorem 4.1. *Suppose that Assumption 2.1 holds. Then the first cluster of network (5) is synchronized for a sufficiently large coupling strength ϵ_1 and the following adaptive control laws:*

$$\dot{c}_i(t) = - \sum_{j=M+1}^{M+k_2} c_{ij} e_i^T (y_j - x_i), \quad i = M+1-k_1, \dots, M. \quad (10)$$

Proof. See [2].

The dynamical evolution of the adaptive coupling strength c_i when (1) is cluster synchronization is discussed in [2]

Acknowledgements

The research for this work was supported, in part, by the région Haute Normandie France and by the ERDF-RISC.

References

- [1] Junchan Zhao, M.A. Aziz-Alaoui and Cyrille Bertelle, Noise-Induced Topology Identification of Complex Dynamical networks, submitted 2012.
- [2] Junchan Zhao, M.A. Aziz-Alaoui and Cyrille Bertelle, Cluster synchronization analysis of complex dynamical networks by input-to-state stability, *Nonlinear Dynamics*, 2012, DOI 10.1007/s11071-012-0516-x.
- [3] Arenas, A., Díaz-Guilera, A., Kurths, J., Moreno, Y. & Zhou, C. [2008] Synchronization in complex networks, *Phys. Rep* **469**, 93-153.
- [4] Aziz-Alaoui, M. A. [2006], Synchronization of chaos, *Encyclopedia of Mathematical Physics*, **5**, 213-226.
- [5] Barabasi, A. L. & Albert, R. [1999], Emergence of scaling in random networks, *Science*, **286**, 509-512.
- [6] Belykh, I., Belykh, V., Nevidin, K. & Hasler, M. [2003], Persistent clusters in lattices of coupled nonidentical chaotic systems, *Chaos* **13**, 165-178.
- [7] Belykh, V. N., Belykh, I. V., and Hasler, M. [2004], Connection graph stability method for synchronized coupled chaotic systems, *Physica D* **195**, 159-187.

- [8] Belykh, V. N., Belykh, I. V., and Hasler, M., Connection graph stability method for synchronized coupled chaotic systems, *Physica D* **195** (2004) 159-187.
- [9] Belykh, I. V., Belykh, V. N., and Hasler, M., Generalized connection graph method for synchronization in asymmetrical networks, *Physica D* **224** (2006) 42-51.
- [10] Boccaletti, S., Latora, V., Moreno, Y., Chavez, M. & Hwang, D. U. [2006], Complex networks: structure and dynamics, *Phys. Rep.* **424**, 175-308.
- [11] Bollobás, B. [1998], *Modern Graph Theory*, (Springer-Verlag, New York).
- [12] Chen, G. & Ueta, T. [1999], Yet another chaotic attractor, *Int. J. Bifurcation and Chaos* **9**, 1465-1466.
- [13] Chen, L. & Lu, J. [2008], Cluster synchronization in a complex dynamical network with two nonidentical clusters, *Jrl Syst Sci & Complexity*, **21**, 20-33.
- [14] Chen, J., Lu, J., Wu, X. & Zheng, W. [2009], Generalized synchronization of complex dynamical networks via impulsive control, *Chaos*, **19**, 043119 (2009).
- [15] Khalil, H. [2002], *Nonlinear systems*, 3rd ed, (Englewood Cliffs, NJ: Prentice Hall).
- [16] Lorenz, E. N. [1963], Deterministic nonperiodic flow, *Journal of Atmospheric Sciences*, **20**, 130-141.
- [17] Lü, J. & Chen, G. [2002], A new chaotic attractor coined, *Int. J. Bifurcation and Chaos*, **12**, 659-661.
- [18] Lü, J. & Chen, G. [2005], A time-varying complex dynamical network model and its controlled synchronization criteria, *IEEE Trans. Autom. Control*, **50**, 841-846.
- [19] Lu, W., Liu, B. & Chen, T. [2010], Cluster synchronization in networks of distinct groups of maps, *Eur. Phys. J. B*, **77**, 257-264.
- [20] Ma, Z., Liu, Z. & Zhang, G. [2006], A new method to realize cluster synchronization in connected chaotic networks, *Chaos*, **16**, 023103.
- [21] Rössler, O. E. [1976], An Equation for Continuous Chaos, *Phys. Lett. A*, **57**, 397-398.
- [22] Wang, X. F. [2002], Complex networks: topology, dynamics and synchronization, *Int. J. Bifurcation and Chaos*, **12**, 885-916.
- [23] Wu, C. W. & Chua, L. O. [1995], Synchronization in an array of linearly coupled dynamical systems, *IEEE Trans. Circuits Syst. I: Fundam. Theory Appl* **42**, 430-447.
- [24] Zhou, J. & Chen, T. [2006], Synchronization in General Complex Delayed Dynamical Networks, *IEEE Trans. Circuits Syst. I*, **53**, 733-744.
- [25] Watts, D. J. and Strogatz, S. H., Collective dynamics of 'small-world' networks, *Nature* **391** (1998) 440-442.
- [26] Barabasi, A. L. and Albert, R., Emergence of scaling in random networks, *Science* **286** (1999) 509-512.
- [27] Pecora, L. M. and Carroll, T. L., Master stability function for synchronized coupled systems, *Phys. Rev. Lett.* **80** (1998) 2109-2112.
- [28] Belykh, V. N., Belykh, I. V., and Hasler, M., Connection graph stability method for synchronized coupled chaotic systems, *Physica D* **195** (2004) 159-187.
- [29] Belykh, I. V., Belykh, V. N., and Hasler, M., Generalized connection graph method for synchronization in asymmetrical networks, *Physica D* **224** (2006) 42-51.
- [30] León, G. D., Farden, D., and McBRIDE, L. E., A System Identification Approach to Estimating Complex Impedance Spectra from Electrochemical Noise Data, *Advances in Complex Systems* **6** (2003) 575-597.
- [31] Yu, W., Chen, G., Cao, J., Lü, J., and Parltitz, U., Parameter identification of dynamical systems from time series, *Phys. Rev. E* **75** (2007) 067201.
- [32] Chen, L., Lu, J., and Tse, C. K., Synchronization: an obstacle to identification of network topology, *IEEE Trans. Circ. Syst-II* **56** (2009) 310-314.
- [33] Zhao, J. C., Li, Q., Lu, J. A., and Jiang, Z. P., Topology identification of complex dynamical networks, *Chaos* **20** (2010) 023119.
- [34] Jia, C., Wang, J., Deng, B., Wei, X., and Che, Y., Estimating and adjusting abnormal networks with unknown parameters and topology *Chaos* **21** (2011) 013109.
- [35] Khalil, H. K., *Nonlinear systems*, 3rd ed, (Prentice Hall, Inc., 2002).
- [36] Sastry, S. and Bodson, M., *Adaptive Control-Stability, Convergence, and Robustness*, (Prentice Hall, Inc., 1989).
- [37] Besançon, G., Remarks on nonlinear adaptive observer design, *Syst. Control Lett.* **41** (2000) 271-280.
- [38] Lu, W., Chen, T., and Chen, G., Synchronization analysis of linearly coupled systems described by differential equations with a coupling delay, *Physica D* **221** (2006) 118-134.
- [39] Chen, T., Liu, X., and Lu, W., Pinning complex networks by a single controller, *IEEE Trans. Circuits Syst-I* **54** (2007) 1317-1326.
- [40] Yu, W., Chen, G., and Lü, J., On pinning synchronization of complex dynamical networks, *Automatica* **45** (2009) 429-435.

COUPLED HR NEURONS : ON THE INFLUENCE OF THE COUPLING STRENGTH ON THE NEURON DYNAMICS

Stefan Balev and Nathalie Corson ^{*†}

Keywords. Hindmarsh-Rose Neurons, Bifurcation Diagram, Asymptotic Dynamics, Coupling Strength

1 Introduction

Studies concerning coupled neurons have already led to very interesting results on emergent global behaviour such as synchronization phenomena (see for example [6, 7]). While working on this kind of problems, it appears that if coupling neurons could make some collective behaviour appear, it could also drastically change each neuron dynamics. This paper deals with the influence of the coupling strength on one neurone behaviour through bifurcation diagrams and numerical analysis of the asymptotic dynamics of a neuron connected to another.

2 Coupling HR Neurons

The HR model (see [2, 3]) reads as follows,

$$(HR) \begin{cases} \dot{x} &= y + ax^2 - x^3 - z + I \\ \dot{y} &= 1 - dx^2 - y \\ \dot{z} &= \epsilon(b(x - c_x) - z) \end{cases} \quad (1)$$

Parameters a , b and d are experimentally determined, c_x is the equilibrium x -coordinate of the two-dimensional system given by the first two equations of (1) when $I = 0$ and $z = 0$ and parameter I corresponds to the applied current. Finally, parameter ϵ represents the ratio of time scales between fast and slow fluxes across the membrane of a neuron. This HR neuron model can exhibit most of biological neuron behaviour, such as *spiking* or *bursting*. With appropriate parameter settings, the HR model exhibits periodic behavior characterized by fast periods of spiking called bursts, followed by slow quiescent inter-burst periods, as shown in Fig. 1.

Hereafter, for all numerical experiments, we use HR system with the following coordinate changes, see [4], $y =$

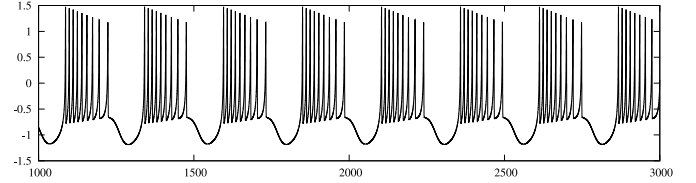


Figure 1: Time series (t, x) of (2) when parameters are fixed as in (5). For this set of parameters values, a HR system exhibit a periodic bursting behaviour.

$1 - y$, $z = 1 + I + z$, $d = a + \alpha$, $c = -1 - I - bx_c$. Applying this transformation, we obtain,

$$\begin{cases} \dot{x} &= ax^2 - x^3 - y - z \\ \dot{y} &= (a + \alpha)x^2 - y \\ \dot{z} &= \epsilon(bx + c - z) \end{cases} \quad (2)$$

Let us consider a network composed by n HR neurons. These neurons are coupled by their first variable x_i . A model of this network is given by

$$\begin{cases} \dot{x}_i &= ax_i^2 - x_i^3 + y_i - z_i - \sum_{j=1}^n c_{ij}h(x_i, x_j) \\ \dot{y}_i &= (a + \alpha)x_i^2 - y_i \\ \dot{z}_i &= \epsilon(bx_i + c - z_i) \end{cases} \quad (3)$$

for $i = 1, \dots, n$, where h is the coupling function and $\{c_{ij}\}$ is the network adjacency matrix. When the neurons are chemically coupled, the coupling function h is given by [4] and reads as

$$h(x_i, x_j) = g_{\text{syn}} \frac{(x_i - V)}{1 + \exp(-\lambda(x_j - \Theta))} \quad (4)$$

where g_{syn} is the coupling strength, Θ is the threshold reached by every action potential for a neuron. Parameter V is the reversal potential and must be larger than $x_i(t)$ for all i and all t since synapses are supposed excitatory. The parameters are fixed as follows throughout this paper,

$$a = 2.8, \alpha = 1.6, c = 5, b = 9, \epsilon = 0.001 \quad (5)$$

$$V = 2, \lambda = 10, \Theta = -0.25 \quad (6)$$

^{*}Stefan Balev is with LITIS, University of Le Havre, France.
E-mail: stefan.balev@univ-lehavre.fr

[†]Nathalie Corson is with LMAH, University of Le Havre, France.
E-mail: nathalie.corson@univ-lehavre.fr

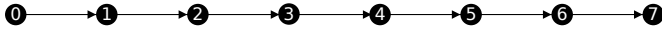


Figure 2: A chain of eight coupled HR neurons

It appears that when neurons are non linearly coupled, complete synchronization can be exhibited only if all the neurons of a network receive the same number of inputs. Moreover, if it is not the case, and under some conditions, a burst synchronization phenomenon can arise. In some previous papers (see [6, 7]), we presented a numerical method for the detection of this burst synchronization phenomenon and some results concerning the value of the coupling strength required to obtain burst synchronization.

3 Main Results

Consider a chain of n non-linearly coupled HR neurons as shown in Fig. 2. In the simplest case $n = 2$, we have two neurons, the first sending signal to the second. The signal received from the second neuron drastically changes its behavior. This change depends on the coupling strength g_{syn} as shows Fig. 3. Note that when the coupling strength is 0 (or equivalently, the neurons are not coupled) all of them have periodic behavior as shows the phase portrait on the left of Fig. 3. Therefore the first interesting result is that a chaotic behavior arises from the coupling for small values of the coupling strength. When we keep increasing this parameter, we observe periodic behavior interval around 1.5, followed by a new chaotic interval. Finally, for large parameter values, the periodic behavior is restored.

The bifurcation diagrams on the bottom of Fig. 3 show similar transition from chaotic to periodic behavior for neurons at higher level of the chain, except that there is no intermediate periodic interval.

Since in [7] we studied the coupling strength needed to make n neurons of a chain synchronize their bursts, we wanted to see if a correlation exists between periodic behavior and burst synchronization. Fig. 3 shows that these two phenomena seem not to be correlated. Surprisingly, in shorter chains neurons synchronize even before they become periodic, but this is not the case in longer chains.

In this extended abstract, we only present results for one kind of network: a chain of non-linearly coupled neurons. Among others, arise the questions of the influence of the network topology and the type of the coupling function on this kind of results.

Acknowledgements

The research for this work was supported, in part, by the RISC Project (Region Haute-Normandie) and the ISCN

References

- [1] Hodgkin A.L., Huxley A.F., *A quantitative description of membrane current and its application to conduction and excitation in nerve*, J. Physiol 117 (1952) 500-544
- [2] Hindmarsh J.L., Rose R.M., *A model of the nerve impulse using two first-order differential equations*, Nature vol. 296, (1982) 162-164
- [3] Hindmarsh J.L., Rose R.M., *A model of neuronal bursting using three coupled first order differential equations*, Proc. R. Sc. Lond. B221 (1984) 87-102
- [4] Belykh I., Lange E., Hasler M., *Synchronization of Bursting Neurons: What matters in the Network Topology*, Phy. Rev. Lett.94, 18, (2005) 188101.1-188101.4
- [5] Izhikevich E.M., *Dynamical systems in Neuroscience*, MIT Press, Cambridge, (2007)
- [6] Corson N., Balev S., Aziz-Alaoui M.A., *Detection of synchronization phenomena in a network of Hindmarsh-rose neuronal models*, ECCS'2010, Lisbon, Portugal, 2010.
- [7] Corson N., Balev S., Aziz-Alaoui M.A., *Burst synchronization of coupled oscillators : towards understanding the influence of the network topology*, ECCS'2011, Vienna, Austria, 2011.

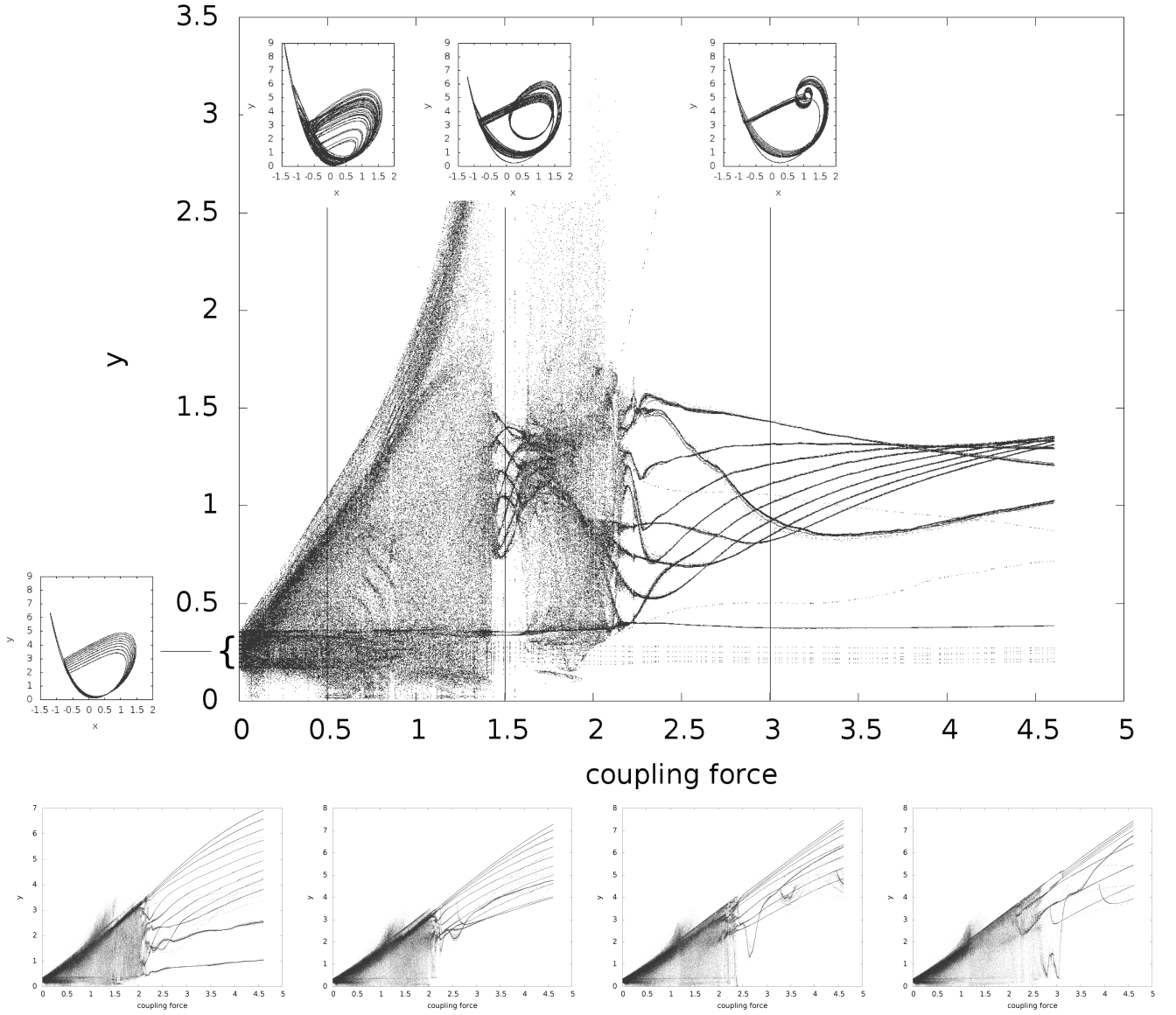


Figure 3: Top: Bifurcation diagram of the second neuron in a chain as a function of the coupling strength parameter. Phase portraits are given for selected coupling strength values: 0, 0.5, 1.5 and 3.0. Bottom: Bifurcation diagrams (from left to right) of the 4th, 8th, 15th and 32nd neuron in a chain.

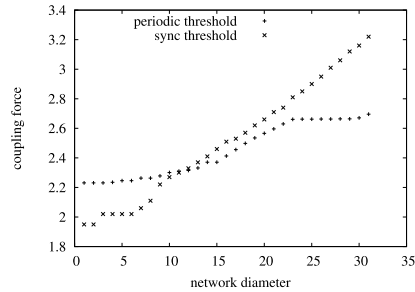


Figure 4: Behavior of a chain of n neurons. For each n we give the minimum coupling strength needed to pass from chaotic to periodic behavior (periodic threshold), as well as the minimum coupling strength needed to observe burst synchronization in the chain (sync threshold).

IMPROVING INDIVIDUAL ACCESSIBILITY TO THE CITY: AN AGENT BASED MODELLING APPROACH

MIRO Team ^{*†}

Abstract. In this work we address the issue of sustainable cities by focusing on one of its very central components, daily mobility. Indeed, if cities can be interpreted as spatial organisations favouring social interactions, the number of daily movements needed to reach this goal is continuously increasing. Therefore, improving urban accessibility merely results in increasing the traffic and its negative externalities (congestion, accidents, pollution, noise...), while reducing at the end the accessibility of people to the city. We therefore propose to investigate this issue from the complex systems point of view. The real spatio-temporal urban accessibility of citizens can not be approximated just by focusing on space and implies to take into account the space-time activity patterns of individuals, in a more dynamic way. However, given the importance of local interactions in such a perspective, an agent based approach seems to be a relevant solution. This kind of individual based and "interactionist" approach allows exploring the possible impact of individual behaviours on the global behaviour of city but also the possible impact of global measures on individual behaviours.

Keywords. Accessibility, Agent-based modelling, Cities, Urban Modeling, Urban planning

Extended Abstract

Our approach is largely based on the conceptual framework of "time geography" defined by Torsten Hagerstrand (see [1]) in the 1970's. This underlying approach can be summarized with a few broad unifying principles:

- movement should be treated as a demand deriving from demands for other activities independent of mobility itself,
- we should focus no longer on simple and segmented movements but upon sequences, chaining of trips. Therefore, we should examine closely the chaining and duration of activities and trips,
- spatial, temporal and social constraints should be incorporated, and similarly, the interactions between individuals and between individuals and their environment,

- it is crucial to recognise interdependencies between events separated in space and in time,
- finally, activities and movements should be analysed in a fundamentally dynamic manner.

In such perspective, the connection with agent-based modelling is quite natural and provides both an elegant and efficient way to explore various issues related to sustainable cities. One of the key issues relates closely to the following question: under which conditions will non coordinated but interdependent local actions eventually lead to the emergence of global spatial configurations of interest? That issue, we develop a model based on an agent based framework: NetLogo [2]. This toy model allows us exploring city configurations (see figure 1) to evaluate for example service accessibility or using.

Let's imagine a very simplified city composed of a regular network. Each node of this network may remains unoccupied or host, with a given probability, one of the following "reservoirs": a residence, a workplace, a public service, a commercial service. A population of virtual citizens is then generated. For each one of them, a residence and workplace are randomly, and the "citizen" is initially located on the node corresponding to its residence (a residence may host several "citizens"). Each "citizen" then chooses a public service and a commercial service, such that the total trip chain minimises the travel time of the "citizen". Each of these agents will have to perform the same trip chain, driving: Residence - Workplace - Public Service - Commercial Service - Residence.

$$V_i = V_{fi} e^{-\alpha(\frac{n_i}{K_i})} \quad (1)$$

Each edge of the network is valued by a maximum speed and the speed of each agent is defined during the simulation with a deterministic Single-Regime speed-Density function specified by equation 1 where [4]:

- V_i the speed of vehicles driving on edge i ,
- V_{fi} the free-flow speed (maximum speed) of edge i ,
- C_i the maximum traffic capacity of edge i ,
- n_i the number of vehicles driving of edge i and

^{*}Contact Author Nicolas Marilleau, IRD, Paris. E-mail: nicolas.marilleau@ird.fr

[†]Manuscript received ; revised

- α a congestion impact factor

At the end of the simulation (i.e. when every "citizen" is back home), public and commercial services (initially located at random on the regular network) may change node, especially if two few "citizens" included them in their trip chain. Two distinct strategies are then implemented:

- non satisfied public services will "listen" to non satisfied "citizens" (i.e. those "citizens" for whom the travelling time corresponding to the public service part of their trip chain exceeds a given threshold) and will get closer to it, under the constraint of a minimum population coverage threshold,
- non satisfied commercial services will try to find a free node characterised by a high traffic, in order to increase their chance to be included in "citizens" trip chains.

Given that "citizens" residences and workplaces are fixed and that no capacity constraints (road + services) are taken into account, it seems quite obvious that public and commercial services will tend to concentrate, under the constraint of residences and workplaces locations. However, introducing constraints (road + services) will amplify the feedback between "citizens" and services and will inevitably increase the complexity of both processes and patterns. Our presentation will focus on this specific point

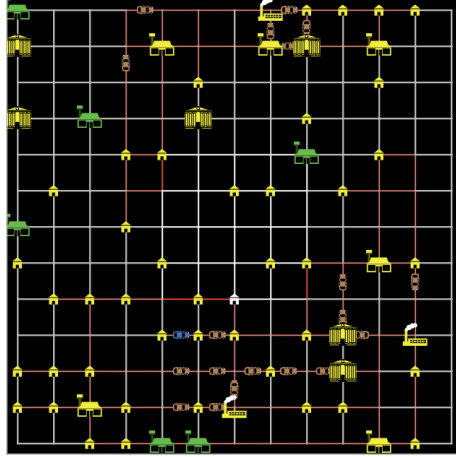
This Netlogo toys model is designed in an experimental way while we are creating and developing a large scale model based on GIS and enquiries done at two middle sized towns (Dijon and Grenoble, France). This second model based on GAMA [3] applies to real case studies hypothesis that were established thanks to the Netlogo toy model.

Acknowledgements

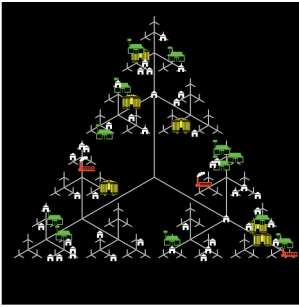
The research for this work was supported by the French ANR "Sustainable Cities"

References

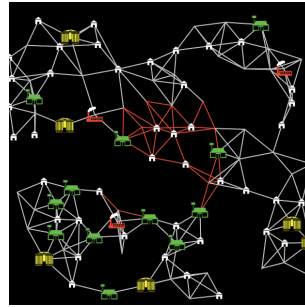
- [1] T. Hagerstrand, "What about people in regional science" *Papers of the Regional Science Association*, vol. 24, pp. 7-21, 1970.
- [2] E. Sklar, NetLogo, a multi-agent simulation environment., *Artificial Life*, 13(3): 303-311, 2011
- [3] P. Taillandier, A. Drogoul, D.A. Vo and E. Amouroux, GAMA: a simulation platform that integrates geographical information data, agent-based modeling and multi-scale control. *In The 13th International Conference on Principles and Practices in Multi-Agent Systems (PRIMA)'2011*, India, Volume 7057/2012, pp. 242-258, 2012
- [4] R. Underwood, Speed, Volume, and Density Relationship *Quality and Theory of Traffic Flow*, Yale Bur. Highway Traffic, New Haven, Connecticut, 1961.



(a) Regular network



(b) Fractal network



(c) Customized network

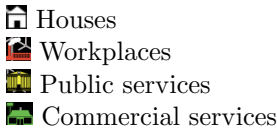


Figure 1: Example of city configurations

CO-EVOLUTION OF THE ROAD NETWORK AND THE LAND USE IN A CITY

Merwan Achibet, Stefan Balev, Antoine Dutot, Damien Olivier ^{*†}

Keywords. Urban system, city morphogenesis, Voronoi diagram, cellular automaton.

Gathering issues of human, economic, geographic and political nature, the city truly is a complex system. The increasing growth in population produces urban systems like the world has never seen before, of increasing size, increasing heterogeneity and increasing complexity. Studying the relationships between its internal elements is fundamental to the understanding of its mechanics and to better predict their development. This work focuses on the relationship between the pattern of human installations within the city – characterized at the atomic level by a basic subdivision, the land lot – and its road network.

Systematic definitions of the city are many. Through the anthropologist's eye it can be seen as a concentration of persons, the economist will prefer to view it as a support for the exchange of financial and physical assets and the urbanist as a functional entity composed of flows and services. We choose to consider that the evolution of a city is driven by its population, translated as a measure of its density. This goes in hand with our focus as land lots are inhabited by the same people that use the surrounding roads to go from one place to another and urbanistic decisions are motivated by a need to optimize the city, streamlining transport means and avoiding high contrasts in the urban fabric.

Study of the domain of urban simulations shows that available scientific works can be classified in two different categories. For visual rendering purposes, special effects in movies or video games, methods have been proposed that generate visually satisfying cities without regarding realism as an obligation [3, 5]. These are often based on empirical observations and the main idea is to emulate the street patterns found in any urban system. Scientific modeling, on the other hand, prefers to focus on the inner qualities of a city, often by studying a subset of those, to analyze its current state and extrapolate its future. We orient our research with the latter in mind but the former

represents a non-negligible source of inspiration.

A reader browsing through the field literature will often encounter cellular automata [6, 7, 1]. These structures, which applicability and potential complexity has been proven over times, are fit for describing any kind of space-related problem. Nevertheless, their rigorous formalism may sometimes restrain realism and negatively impact the validity of the model. For example, a cellular automaton topology is, by definition, perfectly regular and representing a city with a set of identical and aligned cells seems like a coarse simplification. In the same way, the fact that each cell has an identical neighborhood structure, the temporal synchronism and the state discretization may be questioned [4]. We take a step towards realism and embrace the spatial aspect of the city by replacing the classic cellular automaton with a Voronoi diagram [2] following the same basic concepts. Each of its cells represents a land lot and neighborhood relationships that are ruled by adjacency determine its future state; the regularity constraint is thus relaxed. Voronoi edges delineate the Voronoi space of land lots and, as such, are perfect supports for roads.

The different elements represented in our model (*i. e.* land lots and roads) are declined in two flavors. *Potential* elements have an ethereal status; their spatial characteristics are known but until they are definitely built, they have no direct effect on the overall city and only represent an idea, a possible outcome. *Built* elements were potential elements that have been constructed. They form the physical city. Concisely, the gist of the model is to add potential elements to the city and, only later, chose which ones will be built and which ones will be forgotten. The road network expands to accommodate the growth in density and to support anticipated land lots. This process has been divided into three separate mechanisms.

The cellular part of the model lets the inner variables of the city vary based on the Voronoi tessellation and a set of simple rules. Here, only population density is considered and, as a result, the characteristic gradual patterns found in most of the cities of the world is reproduced.

Whereas the previous part of the model is ensuring vertical growth, the horizontal component of the evolution of the city is handled by an extensible method based on

^{*}LITIS, Le Havre University, France. E-mails: {achibetmerwan, antoine.dutot, stefan.balev, damien.olivier}@gmail.com

[†]This work is partially supported by the PREDIT project REMUS

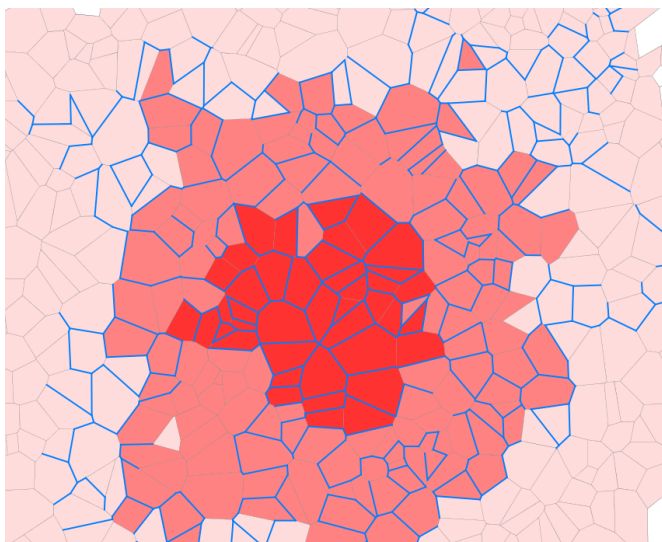


Figure 1: Example of simulation result after 70 time steps. Brighter color corresponds to higher lot density. The road network is in blue.

the use of vector fields. Each piece of information that we want to consider is represented by a vector field that will guide the placement of new lots. For example, a field escaping from high density areas is used to ensure urban sprawl. Another makes new lots move towards the closest roads so that they remain snapped to the main transport axes. All vector fields are then summed up with varying coefficient. This general approach can model any kind of guidance or constraint; in particular obstacle avoidance so that the city does not extend on forbidden areas like lakes, beaches or protected forests.

The third and last mechanism chooses which of the potential elements are to be permanently built. Potential roads are chosen with respect to their contribution to the global network, by means of a network flow evaluation. Potential land lots are chosen depending on their position relative to the built roads and the date of their addition into the potential domain.

We have developed a simulator implementing our model. An example of urban fabric produced by the simulator is shown on Fig. 1. An ongoing work consists in testing different growth strategies, tuning the model parameters and comparing the simulation results to real data. The main difficulty in validating our model is the lack of consistent historical data on the evolution of the cities.

Some preliminary measurements carried on the road network show encouraging results. For example the average degree stays almost constant during the simulation and is close to the average degree observed in real road networks. The evolution of the network diameter is shown on Fig. 2. One can observe phases of city expansion characterized by peaks of the diameter. After these phases accessibility is quickly improved by the densification of the network. Excluding the peaks, the network diameter

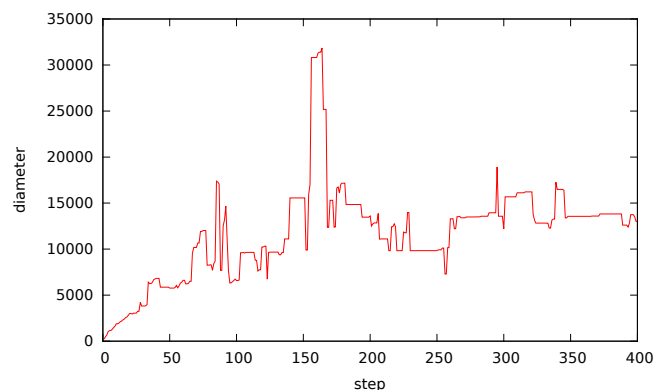


Figure 2: Evolution of the diameter of the road network during the simulation.

scales roughly as the square root of the number of nodes, which is also a property observed in real road networks.

References

- [1] Lucien Benguigui, Daniel Czalanski, and Rafael Roth. Modeling cities in 3d: a cellular automaton approach. *Environment and Planning B: Planning and Design*, 3, 2004.
- [2] Geoffrey Edwards. The voronoi model and cultural space: Applications to the social sciences and humanities. In *COSIT*, 1993.
- [3] George Kelly and Hugh McCabe. Citygen: An interactive system for procedural city generation. In *Game Design & Technology Workshop*, 2006.
- [4] David O’Sullivan. Exploring spatial process dynamics using irregular cellular automaton models. *Geographical Analysis*, 33(1), 2001.
- [5] Yoav I. H. Parish and Pascal Mller. Procedural modeling of cities. In *SIGGRAPH ’01*, 2001.
- [6] Waldo Tobler. Cellular geography. Technical report, International Institute for Applied Systems Analysis, 1975.
- [7] Paul M. Torrens and David O’Sullivan. Cellular automata and urban simulation: where do we go from here? *Environment and Planning B: Planning and Design*, 28, 2001.

COMPLEX SYSTEMS IN EDUCATION: INTERNATIONAL STUDY OF MULTIDISCIPLINARY INTERACTIONS FOR PROMOTING THE LEARNING OF MATHEMATICS AND SCIENCE

René Lozi, Nicole Biagioli ^{*†}

Abstract. A four languages international survey on school systems is examined in the frame of complex networks. Unexpected differences are highlighted between countries when the cross relationships between disliked and useful school subject are considered.

Keywords. Mathematics learning, science learning, multidisciplinary interactions, complex systems, international survey.

1 Introduction

The multidisciplinary study of complex systems in the physical and social sciences over the three past decades has led to the articulation of important new conceptual perspectives and methodologies that are of value to researchers in these fields.

The main goal of this article is to apply these new conceptual perspectives for promoting the learning of mathematics and science which have to be improved in most of the european countries.

The results of the 2009 PISA survey (PISA is the acronym for the OECD programme for international student assesment) highlight that:

"Korea and Finland are the highest performing OECD countries, with mean scores of 539 and 536 points, respectively. However, the partner economy Shanghai-China outperforms them by a significant margin, with a mean score of 556. Top-performing countries or economies in reading literacy include Hong Kong-China (with a mean score of 533), Singapore (526), Canada (524), New Zealand (521), Japan (520) and Australia (515). The Netherlands (508), Belgium (506), Norway (503), Estonia (501), Switzerland (501), Poland (500), Iceland (500) and Liechtenstein (499) also perform above the OECD mean score of 494, while the United States, Sweden, Germany, Ireland, France, Denmark, the United Kingdom, Hungary, Portugal, and partner economy Chinese Taipei

have scores close to the OECD mean" [1].

Moreover: "The results from the 2009 PISA assessment reveal wide differences in educational outcomes, both within and across countries. The education systems that have been able to secure strong and equitable learning outcomes, and to mobilise rapid improvements, show others what is possible to achieve. Naturally, GDP per capita influences educational success, but this only explains 6% of the differences in average student performance. The other 94% reflect the potential for public policy to make a difference. The stunning success of Shanghai-China, which tops every league table in this assessment by a clear margin, shows what can be achieved with moderate economic resources and in a diverse social context. In mathematics, more than a quarter of Shanghai-China's 15-year-olds can conceptualise, generalise, and creatively use information based on their own investigations and modelling of complex problem situations. They can apply insight and understanding and develop new approaches and strategies when addressing novel situations. In the OECD area, just 3% of students reach that level of performance" [2].

One can conclude as said in PISA programme: "While better educational outcomes are a strong predictor of economic growth, wealth and spending on education alone are no guarantee for better educational outcomes. Overall, PISA shows that an image of a world divided neatly into rich and well-educated countries and poor and badly-educated countries is out of date" [2]. The main question which can arise then is: how to achieve a good level in mathematics and science in France and other european countries as done in China, Korea or Finland ?

With a team of researchers in various school subjects (we will call thereafter "discipline" every school subject) we have conducted, between 2006 and 2012, an international survey, using Internet, on several aspects of national school systems, under the pretext of asking readers of the famous worldwide saga "Harry Potter", on the characters created by J. K. Rowling [3]. Among a panel of 177 questions, some though hidden, were directly connected to the scholar system of the countries related to one of the four languages in which the sur-

^{*}René Lozi is with the Laboratory J. A. Dieudonné, CNRS U.M.R. 7351 and the Laboratory I3DL, InterdiDactiques, Didactiques des Disciplines et des Langues E. A. 6308 E-mail: rlozi@unice.fr

[†]Nicole Biagioli is with the laboratory I3DL, InterdiDactiques, Didactiques des Disciplines et des Langues E. A. 6308. E-mail: biagioli@unice.fr

vey was conducted. We have obtained more than 9000 questionnaire replies (517 in english, 5250 in french, 1851 in german, 1608 in spanish). Of course the language of the survey is not uniquely related to one country, as for an example, people from 18 countries have replied in spanish: Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, Spain, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, El Salvador, Uruguay and Venezuela.

With the help of the replies on only few questions we show that the solution of the problem of achieving a good level in mathematics and science is not obvious and requires the analysis of complex relations. Such an analysis is similar to the analysis of complex systems. Further studies varying several parameters (sex, age, education level, taste for particular school subjects) are therefore needed in order to improve educational systems.

2 Raw results of the survey

Therafter we consider only three questions of our international survey and the relationship between the replies.

These questions are:

- In your opinion, which subject taught in the actual world is the most useful (one single answer) ?
- In the actual world, what is the school subject you dislike (only one single answer) ?
- In the actual world, what is your favorite school subject (only one single answer) ?

Of course these questions were not placed together in the questionnaires (their position were in 80th, 120th and 132nd places) as not to come to the attention of the Harry Potter's fans. The possibles replies have to be chosen among the following ones: Mathematics, History, Geography, Native language (of each survey), Philosophy, Business and social science, Physics, Chemistry, Natural sciences, Technology, Foreign language, Ancient languages (Greek, Latin), Fine Arts, Music and choir, Sport.

Building the survey we were aware of gender study: concerning mathematics PISA 2009 shows that on average across OECD countries, boys outperformed girls, with an advantage of 12 score points [2, p.137]. However gender differences in science performance tend to be small, both in absolute terms and when compared with the large gender gap in reading performance and the more moderate gender differences in mathematics. As our purpose is to promote the learning of mathematics and science, our priority is to consider first the replies of the female gender. Figures 1 to 4 display the results of the women above 15 years old in the english, french, german and spanish surveys for the question on the disliked discipline. The respective numbers of replies are: 319, 2959, 1065, 828. Uneventful, Mathematics is the most disliked discipline for the women of every country, ranking from 22,8 % (german) to 34,8 % (english). Then Sport is the second one and Physics the third one (excepted for spanish women

who give History in the third position). In fourth position we find Business and social science (french survey), Chemistry (english and german), Physics (spanish).

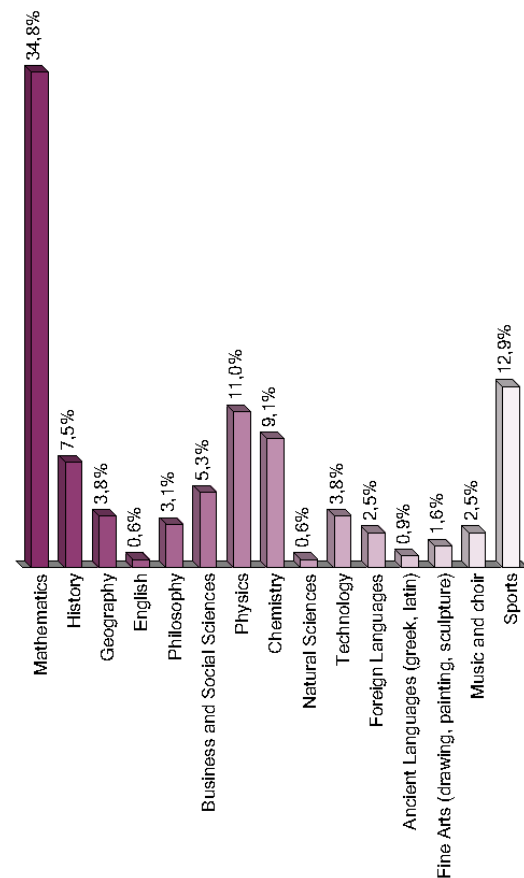


Figure 1: Disliked school subjects for english women above 15 years old

These results are very similar whatever the country. However if we consider crossed results between disliked and most useful subject school in the actual world, we obtained surprising differences.

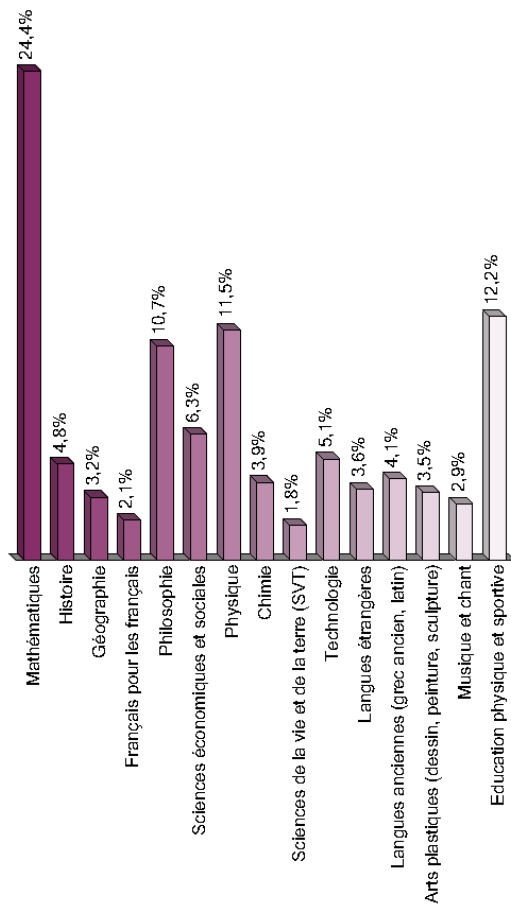


Figure 2: Disliked school subjects for french women above 15 years old

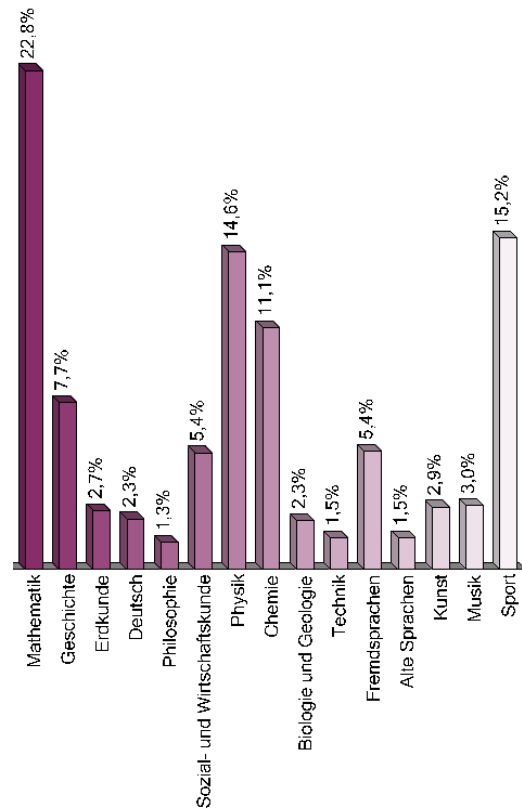


Figure 3: Disliked school subjects for German women above 15 years old

3 Network analysis

We have considered simultaneously replies of both questions:

- In your opinion, which subject taught in the actual world is the most useful ?
- In the actual world, what is the school subject you dislike ?

For these two questions we have done a principal component analysis (PCA) of the results (PCA is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to (i.e., uncorrelated with) the preceding components [4]). We display the results of the most significative correlations between disciplines in Figs. 5 (french), 6 (german) and 7 (english). The black arrows stand for very significative correlation, the dashed blues arrows for significative correlation and the dotted pink arrows for less significative ones.

Fig. 8 displays useful school subjects in the actual world for french women above 15 years old.

It is unexpected that the complexity of the networks are very different between french survey (which is mainly related to the french's school system), german survey (related to german's school) and english one (related mainly to U.S.A.'s school system). The complexity of the french network for the cross analysis seems more important than the german network. The english network is the simplest one (the spanish network stands between the german and the english). In these network we have only displayed the positive correlations. Due to the complexity of the figure the analysis of both positive and negative correlation will be done using tables.

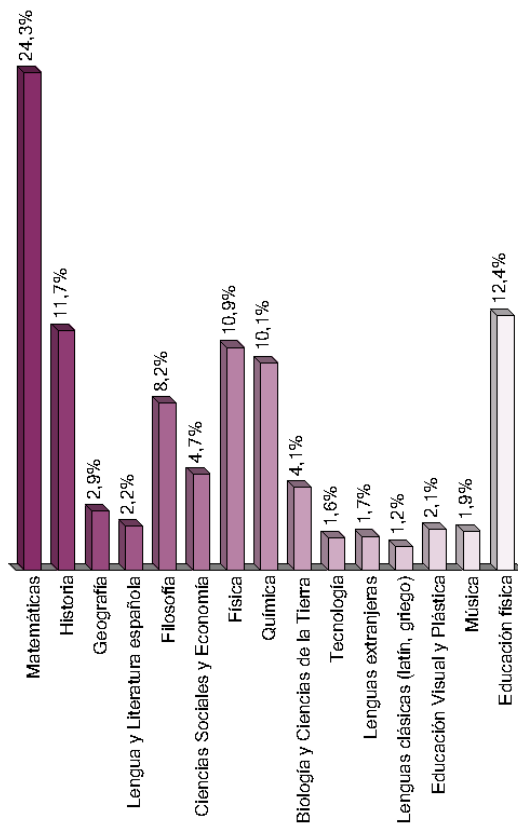


Figure 4: Disliked school subjects for Spanish speaking women above 15 years old

4 Other results

In this section, we consider the other replies and the cross relationship between them. Fig. 9 shows liked school subjects for women above 15 years old, while Fig. 10 displays disliked school subjects for men above 15 years old.

This figure is interesting when compared to Fig. 2 : native language, Philosophy, foreign languages, ancient languages, Fine Arts, Music and choir are more disliked by men than women. Instead, Mathematics, Physics, Technology and sports are less liked. One can say that men are more "scientific" than women. One can also compare useful school subjects between men and women (see Fig. 11 for french men and Fig. 8 for women) and also liked ones versus gender (see Fig. 12 for french men and Fig.

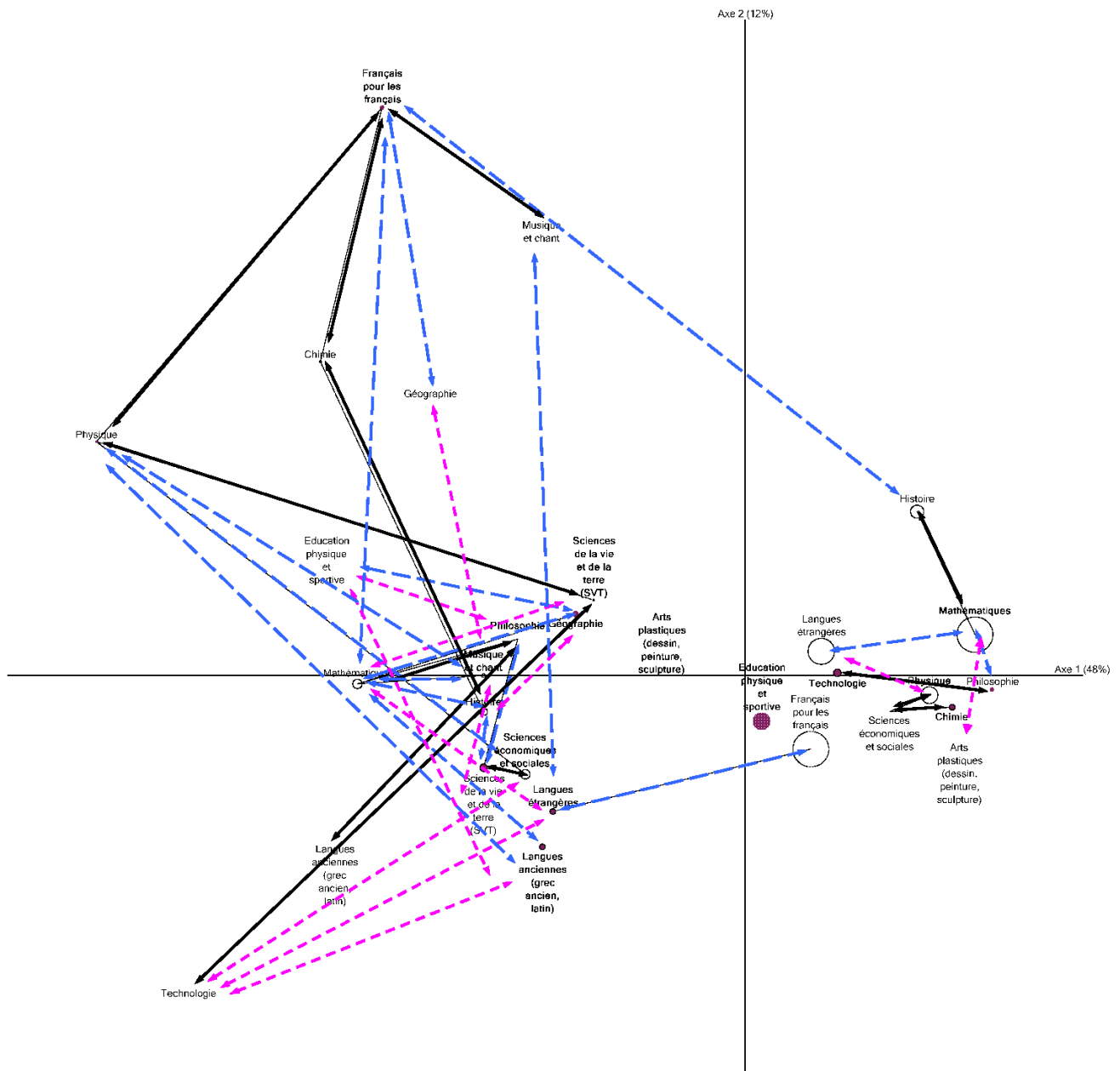


Figure 5: French network analysis

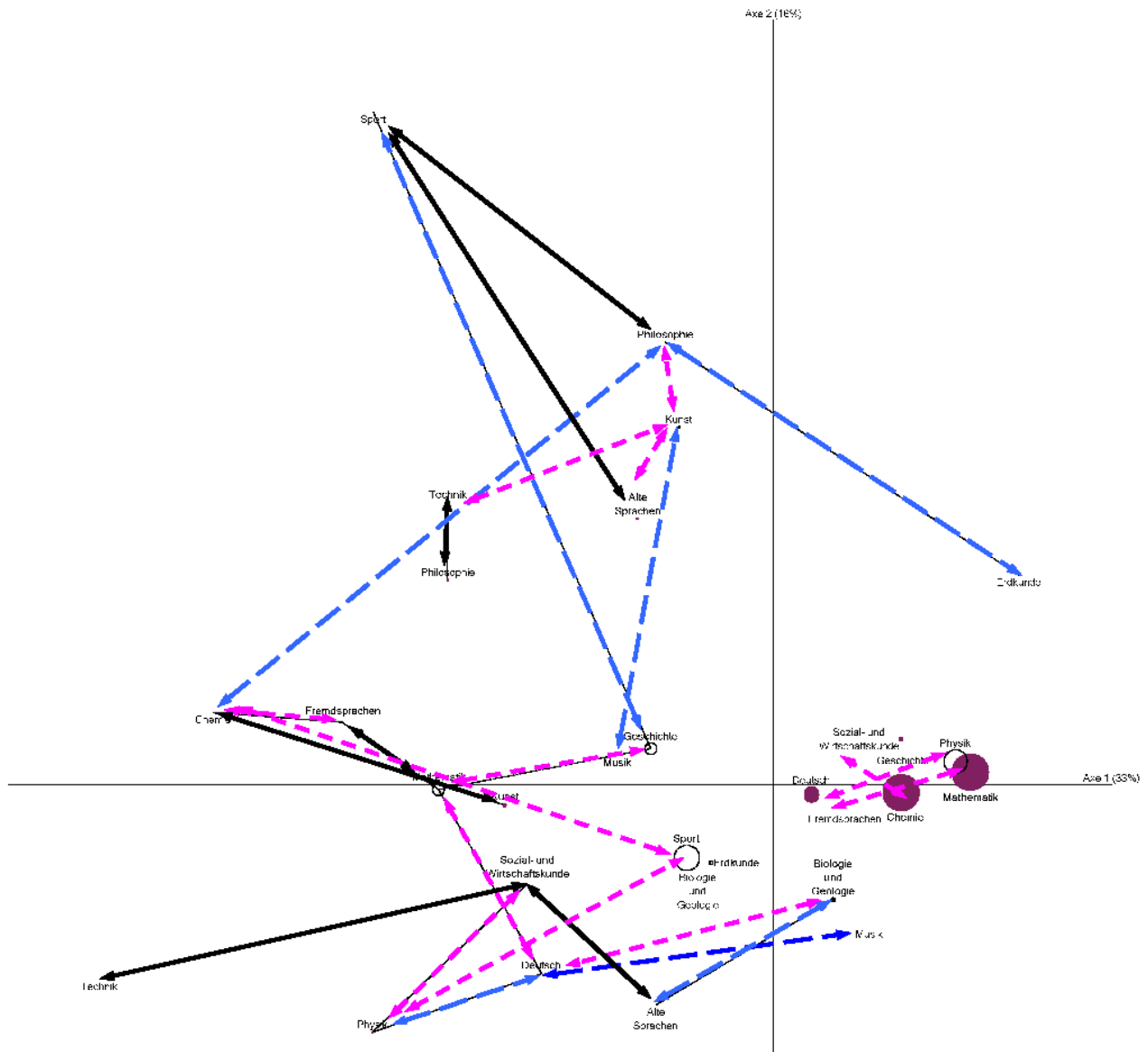


Figure 6: German network analysis

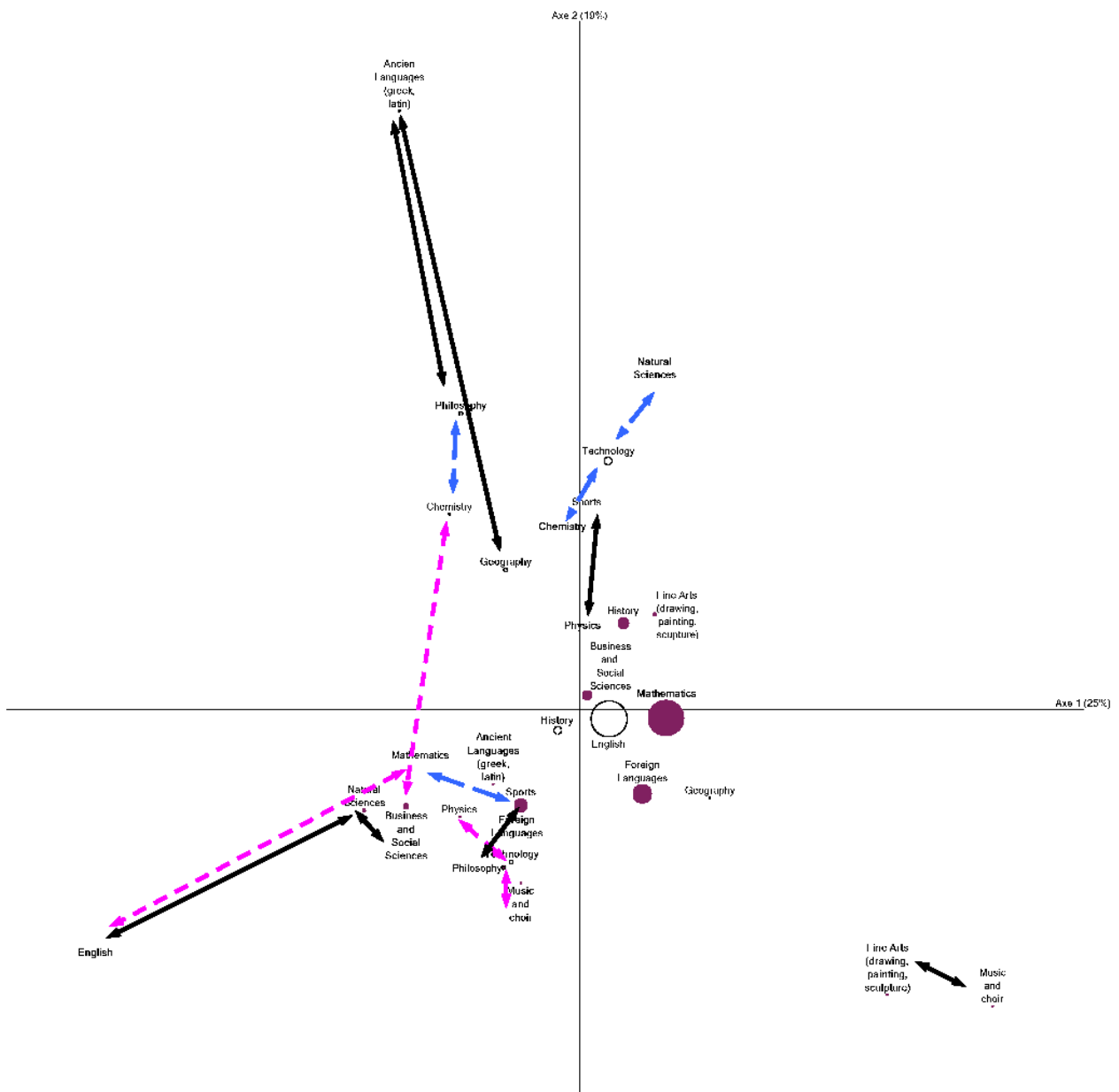


Figure 7: English network analysis

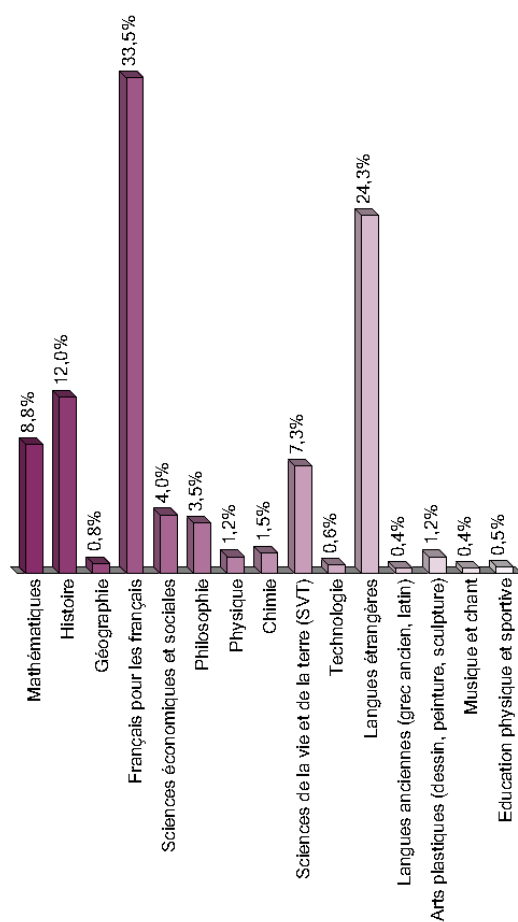


Figure 8: Useful school subjects for french women above 15 years old

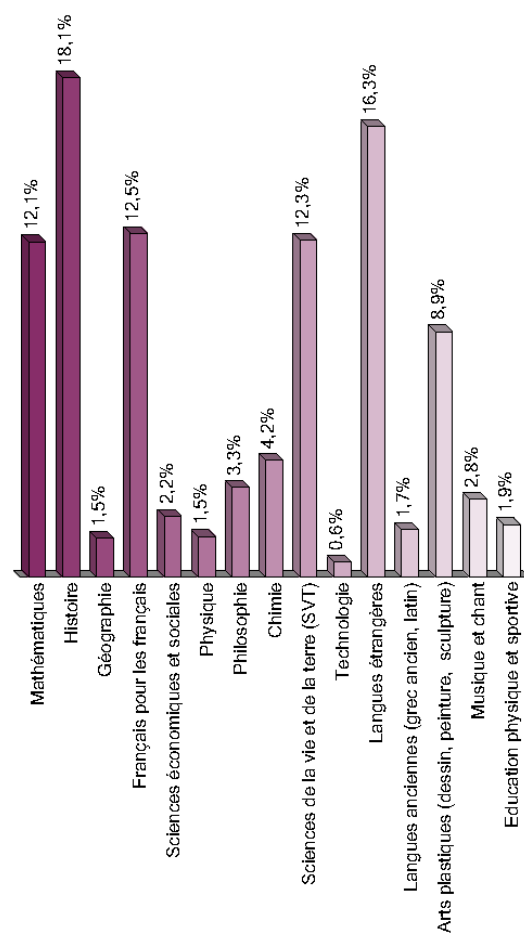


Figure 9: Liked school subjects for french women above 15 years old

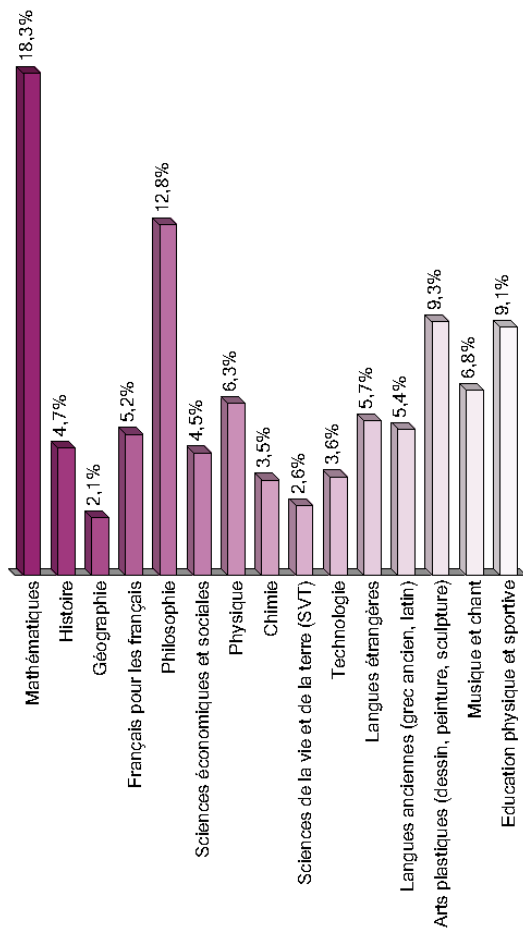


Figure 10: Disliked school subjects for french men above 15 years old

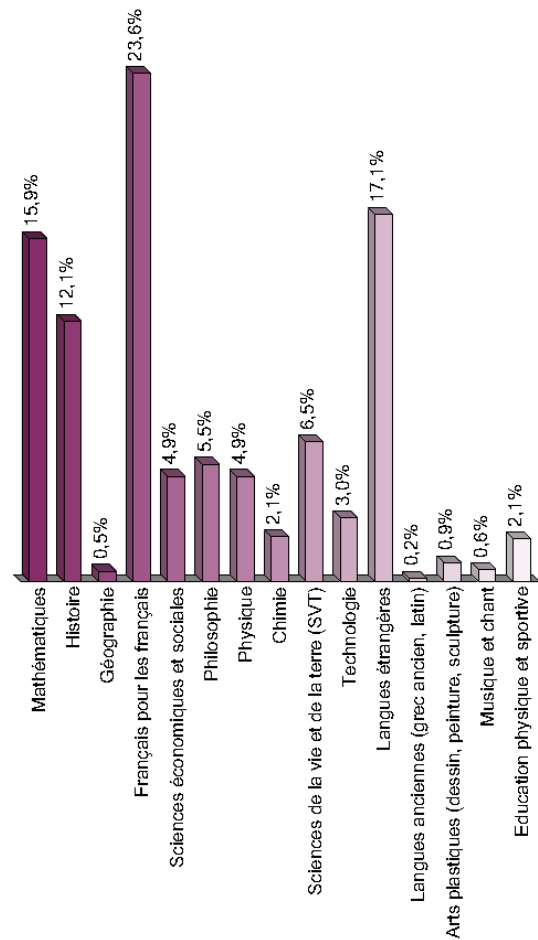


Figure 11: Useful school subjects for french men above 15 years old

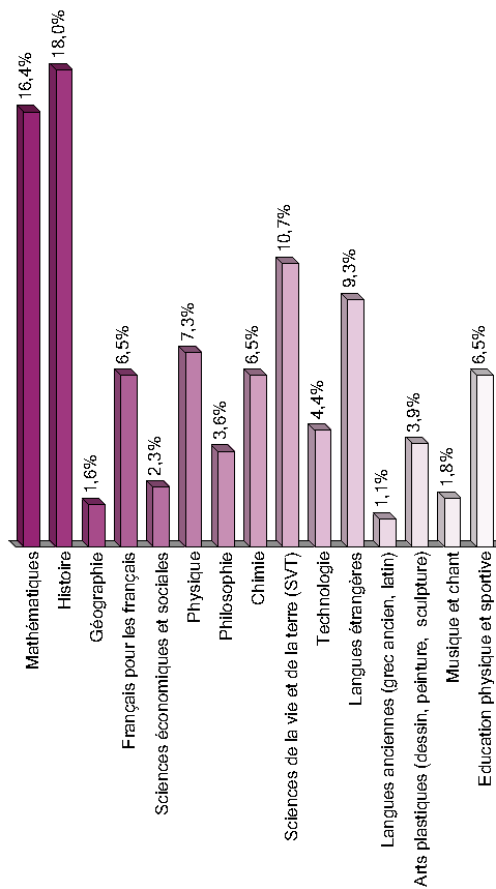


Figure 12: Liked school subjects for french men above 15 years old

9 for women). Due to the limited extend of this article we do not display the corresponding comparison for the surveys in others languages.

Table 1		
School subjects	Useful	Disliked
Mathematics	A	1
History	B	2
Geography	C	3
Native language	D	4
Philosophy	E	5
Business social sci.	F	6
Physics	G	7
Chemistry	H	8
Natural sciences	I	9
Technology	J	10
Foreign language	K	11
Greek, Latin	L	12
Fine Arts	M	13
Music and choir	N	14
Sport	O	15

In order to extend the network analysis of previous section, we give some examples of correlation tables. School subjects are symbolized by letters for useful ones and by numbers for disliked (see Table 1).

Table 2 displays both positive and negative significant correlations between disciplines from the english survey.

+VS means positive very significant correlation, +S :positive significant correlation, +LS: positive less significant

and -VS, -S, -LS have the same meaning for negative correlations.

Table 2		english				
	+VS	+S	+LS	-LS	-S	-VS
1						A
2						
3	L					
4	I		A			
5	L	H				
6	I		H			
7	O					
8		J				
9		J				
10			G			
11	E		F			
12						
13	N					
14			F			
15		A		B		

The first three columns are equivalent to the graph of Fig. 7, meanwhile the three last ones are not represented here by any graph.

Table 3 shows the more complex situation for the french survey when both positive and neagative correlations are plotted.

	Table 3		french			
	+VS	+S	+LS	-LS	-S	-VS
1	B	E,K	M	C,L	J	A,G,I
2	H	A,I	C			B
3		A,O		F		
4	G,N,H	A,B,C				D
5	A,L	I	O	F	D	E
6	I	G	J		B,F	
7	F		K	H,J	A,G,I	
8	F			A		
9	G,J		A	I		
10	E					
11		D,N	A,J			K
12		A,G	J,O			B
13	M	H	G			
14		A,G	G,I			
15				B		

The same comparison can be done for german (Table 4) and spanish survey (Table 5)

	Table 4		german			
	+VS	+S	+LS	-LS	-S	-VS
1			K			A
2		O	A		B	
3						
4		G,N	A,I		D	
5	O	C,H	M	D		
6	J,L		G			
7			K	A,G		
8			F	G		
9		L				
10	E		M			
11	A		H			K
12	O		M			
13	H					
14		M	A			
15			G,H	M		

	Table 5		spanish			
	+VS	+S	+LS	-LS	-S	-VS
1	B		D,F,K,O			A
2	A	J		F	D	B
3			H,J			
4	G	A		D,K		
5			L	E	D	
6		A,O	G	F	K	
7			D;E	I		
8		C	F		I	
9		N		I		
10						
11	C,E					
12						
13		I				
14			A			
15	G	I				

5 Conclusion

As said in the 2009 PISA survey:

"One of the ultimate goals of policy makers is to enable citizens to take advantage of a globalised world economy. This is leading them to focus on the improvement of education policies, ensuring the quality of service provision, a more equitable distribution of learning opportunities and stronger incentives for greater efficiency in schooling. Such policies hinge on reliable information on how well education systems prepare students for life. Most countries monitor students' learning and the performance of schools. But in a global economy, the yardstick for success is no longer improvement by national standards alone, but how education systems perform internationally. The OECD has taken up that challenge by developing PISA, the Programme for International Student Assessment, which evaluates the quality, equity and efficiency of school systems in some 70 countries that, together, make up nine-tenths of the world economy. PISA represents a commitment by governments to monitor the outcomes of education systems regularly within an internationally agreed framework and it provides a basis for international collaboration in defining and implementing educational policies".[2]

We have tried to find a way in order to define a efficient educational policy especially for promoting the learning of mathematics and sciences. With the help of the replies on only few questions we show that the solution of such problem is not obvious and requires the analysis of complex relations. Such an analysis is similar to the analysis of complex systems. Discrepancies appear from one country to another. Further studies varying several parameters (sex, age, education level, taste for particular school subjects) are therefore needed in order to improve educational systems. It seems that there remains a long way for that.

References

- [1] PISA 2009 Results: Executive Summary, <http://www.oecd.org/dataoecd/34/60/46619703.pdf>
- [2] PISA 2009 What Students Know and Can Do: Student Performance in Reading, Mathematics and Science (Volume I), http://www.oecd.org/document/53/0,3746,en_32252351_46584327_46584821_1_1_1_1,00.html.
- [3] Rowling, J. K. (1997). *Harry Potter and the Philosopher's Stone*. Londres: Bloomsbury.
- [4] Baccini, A. "Statistique descriptive multidimensionnelle", *Publications de l'Institut de Mathématiques de Toulouse*, mai 2010.

Searching Shortest Paths in Weakly Dynamic Graphs

Jean-Yves COLIN, Moustafa NAKECHBANDI, LITIS, Le Havre University.
{moustafa.nakechbandi, jean-yves.colin}@univ-lehavre.fr

Ahmed Salem OULD CHEIKH, Nouakchott University
ahdsalem@gmx.fr

Extended abstract

In complex systems, dynamic graphs in which some of their values or even their topologies may change from one moment to another offer new research opportunities.

One of the most famous algorithm, and one of the most used on static graphs, is the shortest-paths algorithm from E. W. Dijkstra [1]. For the more complex dynamic graphs, several models are proposed, probabilistic [4, 2] or non-probabilistic[7,5]. In non-probabilistic models, most algorithms update previously computed data after each change in a value or after the addition or removal of an edge [8, 10]. In probabilistic models, the optimal paths definition of a shortest (or longest) path is different according to the published papers. The most usual definition sets as optimal a path that maximizes the expected value of an utility function chosen by the author(s) [4, 2]. The problem itself is usually NP-hard.

Among used metaheuristics, one can find ant colony algorithms [9] and other swarm intelligence algorithms. These algorithms are very general and try too to adapt their results following changes in the problem.

In this paper, we study weakly dynamic graphs, and we propose an efficient polynomial algorithm that computes in advance shortest paths for all possibles configurations. No computation is needed after any change in the problem because shortest paths are already known in all cases.

We apply this result to one delivery problem for trucks from one regional storehouse to several local stores when one possible point has a variable traversal duration. We apply too this result to the problem of rerouting delivery trucks toward their final destinations when there is a change in the traversal duration of one known point.

References.

1. E.W. Dijkstra. A note on two problems in connexion with graphs. *Numerische Mathematik*, 1:269-271, 1959.
2. D. Fulkerson, Expected critical path lengths in PERT networks. *Operations Research* 10 808 - 817, 1962.
3. M. Minoux. Structures algébriques généralisées des problèmes de cheminement dans les graphes: théorèmes, algorithmes et applications. *RAIRO, Recherche opérationnelle*, vol.10 n°6, pp. 33-62, 1976.
4. P.B Mirchandani et H. Soroush. Optimal paths in probabilistic networks. A case with temporary preferences. *Computers & Operations Research*, 12:365 - 383, 1985.
5. A. Orda, R. Rom. Shortest-path and minimum-delay algorithms in networks with time dependent edgelenh. *J. ACM* 37(3), 607-625, 1990.
6. G. Ramalingam, T. Reps. On the computational complexity of dynamic graph problems, *Theoret. Comput. Sci.* 158 233-277, 1996.
7. F. Kuhn and R. Oshman. Dynamic networks: models and algorithms. *SIGACT News*, 42(1):82-96, 2011.
8. C. Demetrescu and G. F. Italiano. A new approach to dynamic all pairs shortest paths. *J. ACM*, 51(6):968-992, 2004.
9. S. Balev and F. Guinand and Y. Pigné Maintaining Shortest Paths in Dynamic Graphs. In proceedings of the International Conference on Non-Convex Programming: Local and Global Approaches Theory, Algorithms and Applications (NCP'07). December 17-21, 2007. Rouen.
10. H. Mao, Pathfinding Algorithms for Mutating Graphs. *Computer Systems Lab* 2007-2008.
11. M. Alivand, A.A. Alesheikh and M.R. Malek, New method for finding optimal path in dynamic networks. *World Applied Sci. J.*, 3: 25-33, 2008.
12. H. Bast, E. Carlsson, A. Eigenwillig, R. Geisberger, Ch. Harrelson, V. Raychev, F. Viger. Fast Routing in Very Large Public Transportation Networks Using Transfer Patterns. *ESA* (1), 290-301, 2010.

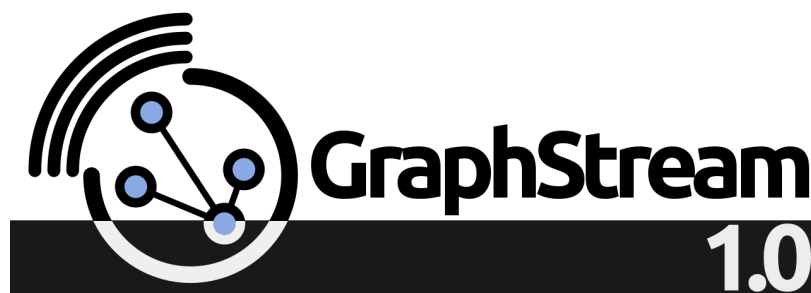
Part II

Practical session/tutorial

GRAPHSTREAM

A JAVA LIBRARY FOR DYNAMICAL COMPLEX NETWORKS

Eric Deussé *



1 GraphStream Description

GraphStream is an open-source java library allowing to manage graphs describing complex networks and their evolutive dynamics.

GraphStream goals are:

- To give practical tools to dynamically manage graphs evolution and associated data for:
 - New measure indicators for complex networks including dynamics;
 - Robust algorithms suited to dynamics.
- To give basic development platform for various applications:
 - Urban mobility and transportation simulations;
 - Adhoc networks;
 - Social networks;
 - Adaptive distributions of dynamical simulations or dynamical systems;
 - Analysis of network morphodynamics.

*Eric Deussé is a collective name emerging from the swarming team RI2C from LITIS laboratory, University of Le Havre, 25 rue Philippe Lebon, BP 540, 76058 Le Havre Cedex, France

GraphStream is based on event model describing graph evolution as stream between a source that produces events and one or more sinks that receive and process these events. Events can be changes in the structure of the graph or in attributes of elements :

- addition or removal of nodes;
- addition or removal of edges;
- addition, update or removal of data attributes;
- time steps.

GraphStream provides a visualization tool to display a graph and its evolution. This tool is able to use existing coordinates of nodes (looking in node attributes), else an automatic force-based layout is provided to compute these coordinates. Style of elements can be customized using a CSS-like stylesheet. Beside the huge family of existing graph libraries, GraphStream focuses on providing additional tools to manage dynamics, but the integration of GraphStream with other libraries is eased by a great number of import/export modules including GraphViz and Pajek file formats, shapefile data format used in geographic information systems, and more other file formats.

A dynamical web site, intended to users from various disciplines, provides documentation, tutorials and videos. It can be found at :

<http://graphstream-project.org>

2 Practical Lab Schedule

During the GraphStream practical lab session, provided in EPNACS satellite meeting within ECCS'11, Vienna, Austria, on September 15 2011, two parts will be developed:

- Part 1: GraphStream, a java library for dynamical complex networks, concepts and introduction to elementary implementations;
- Part 2: Application to simulations for geographical systems.

3 Gallery

In the following various figures, extracted from the video file produced to illustrate the version 1.0 of GraphStream, are presented and commented.



Figure 1: GraphStream algo core: shortest path computation

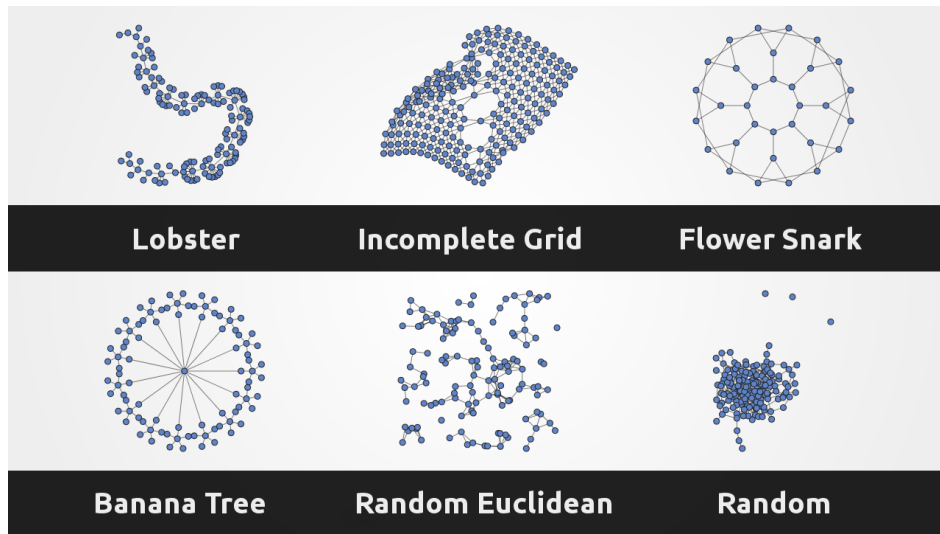


Figure 2: Various graph generators

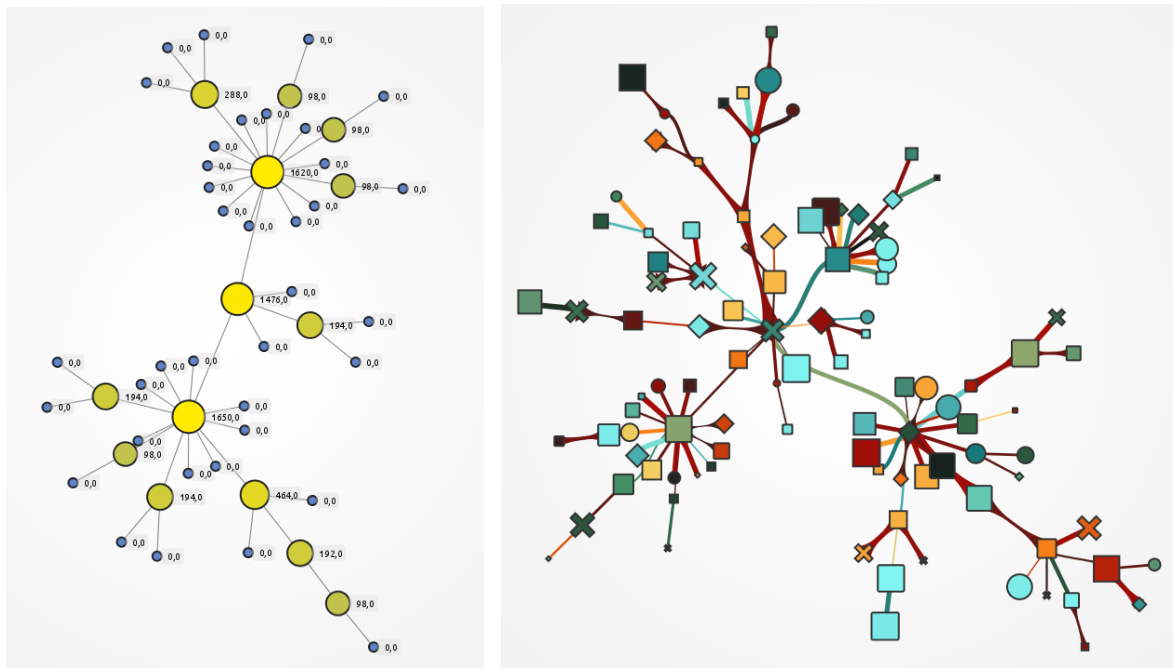


Figure 3: GS algo core; betweenness centrality computation; GS visualization with CSS



Figure 4: Complex network visualization

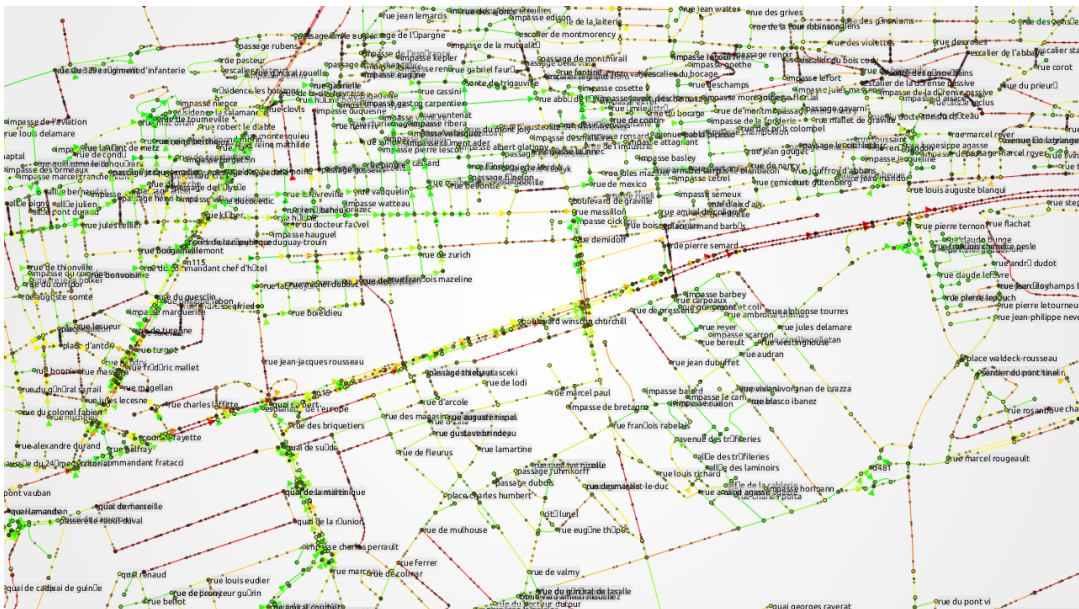


Figure 5: Simulation running on road network extraction from the shapefile of Le Havre city

Index

ACHIBET, M., 15
AZIZ-ALAOUI, M.A., 5
BALEV, S., 9, 15
BERTELLE, C., 5
BIAGOLI, N., 17
COLIN, J.Y., 29
CORSON, N., 9
DEUSSÉ, Eric, 33
DUTOT, A., 15
FRADKOV, A.L., 3
JUNUSSOV, I.A., 3
LOZI, R., 17
MIRO TEAM, 13
MARILLEAU, N., 13
NAKECHBANDI, M., 29
OLIVIER, D., 15
OULD CHEIKH, A.S., 29
SELIVANOV, A.A., 3
ZHAO, J., 5