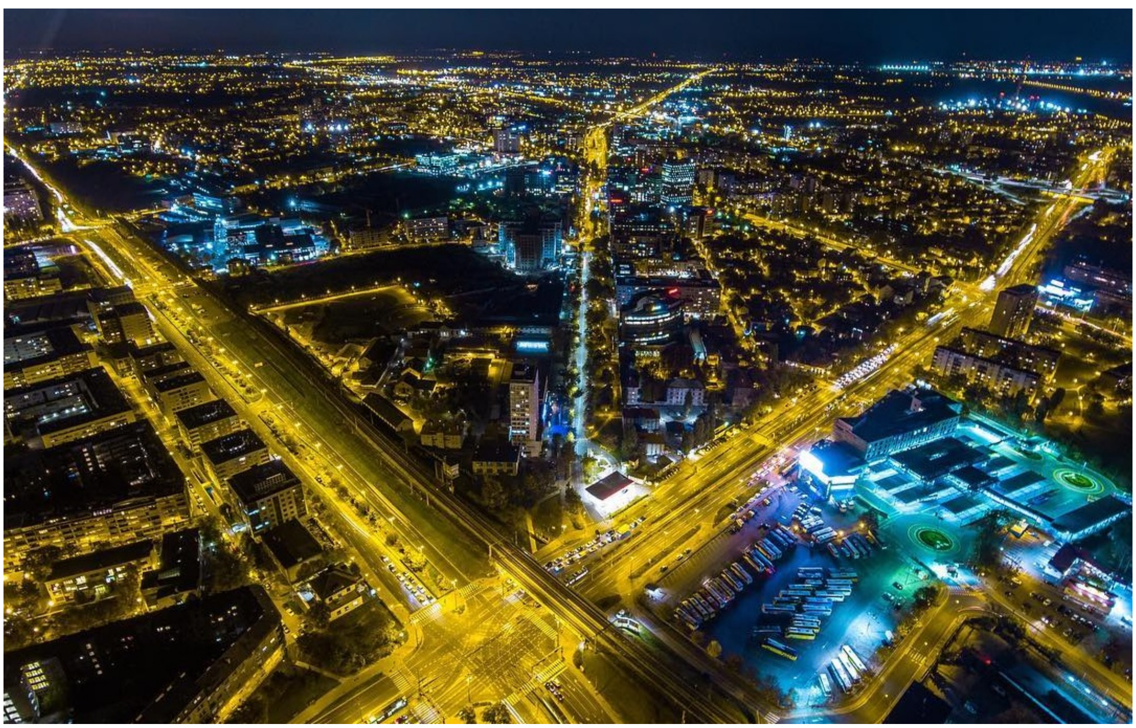
# CA 18232: WG3 MEETING

# Program and Abstracts



24th - 27th of February 2020, Zagreb

## Monday 24.02.2020

**10.00 - 10.30** Welcome meeting
**10.30 - 13.00** Discussions & coffee

**13.00 - 14.30** Lunch break

**14.30 - 15.15** Marjeta Kramar Fijavž page 6
Semigroup approach for dynamical systems on networks.
**15.15 - 16.00** Amir Leshem page 7
Recovering dynamics on networks from stable points.

**16.00 - 16.30** Coffee break

**16.30 - 17.15** Giulia Rotundo page 10
A copula approach to cross-shareholding networks.
**17.15 - 18.00** Discussions

## Tuesday 25.02.2020

**9.00 - 9.45** Plenary talk 1: Representative of WG1
**10.00 - 10.35** Plenary talk 2: Representative of WG3
Nikolay K. Vitanov page 11
Models of motion of substance in channels of networks with applications.
**10.45 - 11.45** Coffee break

**11.15 - 12.00** Plenary talk 3: Representative of WG4

**12.00 - 12.45** Plenary talk 4: Representative of WG5

**13.00 - 14.30** Lunch break

**14.30 - 16.00** MC Meeting

**16.00 - 16.30** Coffee break

**16.30 - 18.00** Discussions

**Wendesday 26.02.2020**

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|---|---|---|
| **9.00 - 9.45** | Alexandre Mauroy<br>Koopman operator-based methods for network identification. | page 8 |
| **9.45 - 10.30** | Andrej Jokić<br>On structure in analysys and control of large-scale dynamical networks. | page 5 |
| **10.30 - 11.30** | Discussions & coffee | |
| **11.30 - 12.15** | Aleksandra Puchalska<br>Dynamical systems on networks in cel proliferation modelling. | page 9 |
| **12.15 - 13.00** | Sergio Gómez<br>Dynamics in multiplex networks. | page 4 |
| **13.00 - 14.30** | Lunch break | |
| **14.30 - 16.00** | Discussions | |
| **16.00 - 16.30** | Coffee break | |
| **16.30 - 18.00** | Discussions | |

# Dynamics in multiplex networks

**Sergio Gómez**
Universitat Rovira i Virgili, Tarragona, Spain

Multiplex networks constitute a particular case of multilayer networks in which nodes belong to several layers at the same time, connecting to other nodes with intra-layer links, and also with instances of themselves at different layers. This kind of structure is useful to represent multi-modal transportation networks, and online social networks, among others. The discovery of new emergent behaviors directly related with the multiplex structure of networks is of utmost importance, since many times the analysis of networks has been performed using aggregated networks, neglecting the real underlaying structure. We will show how the multiplex structure is responsible of super-diffusion phenomena [1], the interaction between epidemic spreading and awareness [2], the diversity of random-walk dynamics [3], or the emergence of congestion due to the structural multiplexity [4]. An important tool for the analysis of these dynamics has been their microscopic description at the level of nodes [2, 4] or links [5].

**REFERENCES**

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# On Structure in Analysis and Control of Large-scale Dynamical Networks

Andrej Jokić
University of Zagreb, Croatia

There exists a widely recognised need to better understand and manage complex large-scale dynamical networks, such as "smart" energy grids, biological networks or automated highways. Complexity, large-scale, interconnection/communication constraints and often non-existence of a suitable global model (e.g, due to confidentiality issues), require development of analytical and computational methods for tractable analysis and controller synthesis under structural constraints (e.g., plug-and-play requirements; structured stability/performance conditions; decentralized or distributed controllers).

The S-procedure and the Kalman-Yakubovich-Popov lemma are two fundamental results widely used both in theoretical studies and in development of constructive numerical algorithms for analysis and controller synthesis of linear time invariant (LTI) systems. Closely related are the notions of dissipativity and integral quadratic constraints. After presenting a suitable review of some of these results, our focus in this talk is on imposing and exploiting certain structural constraints in them when dealing with analysis/synthesis of large-scale LTI dynamical networks. We present some of our recent result of some cases when the S-procedure with structural constraints is lossless, its corresponding interpretation in terms of dissipativity theory and application in analysis of LTI dynamical networks.

# SEMIGROUP APPROACH FOR DYNAMICAL SYSTEMS ON NETWORKS

**Marjeta Kramar Fijavž**
University of Ljubljana, Slovenia

In this survey talk we consider simple dynamical systems (like transport and diffusion processes) taking place along the edges of a metric graph. The systems are modelled by linear first and second order differential equations satisfying different boundary conditions in the vertices. We tackle the problem using methods from the theory of strongly continuous operator semigroups and first rewrite it as an abstract Cauchy problem of the form

$$(ACP_1)\begin{cases}\dot{x}(t) = Ax(t),\\ x(0) = x_0,\end{cases} \qquad \text{or} \qquad (ACP_2)\begin{cases}\ddot{x}(t) = Ax(t),\\ x(0) = x_0,\\ \dot{x}(0) = x_1,\end{cases}$$

for a linear (in general unbounded) operator $A : D(A) \subset X \to X$ on a Banach space $X$. It is well-known that problems $(ACP_1)$ and $(ACP_2)$ are well-posed if and only if $A$ generates a strongly continuous semigroup and a cosine family on $X$, respectively. We will present conditions on the coefficients determining $A$ and the domain $D(A)$ which assure the well-posedness of the corresponding Cauchy problem. Further we discuss some qualitative properties of the solutions.

## REFERENCES

[1] Batkai, A., Kramar Fijavž, M., Rhandi, A.: Positive Operator Semigroups: from Finite to Infinite Dimensions. Birkhauser-Verlag, Basel, 2017.

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# Recovering dynamics on networks from stable points

**Amir Leshem**
Bar Ilan University, Israel

Recovering dynamics in networs is an important problem in many fields of science and engineering. While the easiest way to recover dynamics is using temporal measurements, in many cases this is infeasible. In my talk I will describe an alternative approach to recovery of network dynamics and topology from steady states of different boundary conditions. The approach exploits sparsity which is prevalent in many real networks. I will provide examples of applications to gene networks as well as opinion dynamics in social networks.

# Koopman operator-based methods for network identification

**Alexandre Mauroy**
University of Namur, Namur, Belgium

Jorge Goncalves
University of Luxembourg, Belval, Luxembourg

We will report on a novel framework for network identification (and more generally for nonlinear system identification), which relies on the so-called Koopman operator [1]. This framework is based on the key idea that identifying a nonlinear dynamical system in the state space is equivalent to identifying the linear Koopman operator in the space of observables. Two dual identification methods will be presented in this context and complemented with theoretical convergence results. The methods will be shown to be efficient with a general class of systems, well-suited to low sampling rate data sets, and capable of identifying the nature of the coupling between nodes. If time allows, the extension of the framework to partial differential equations will be presented.

## REFERENCE

[1] A. Mauroy and J. Goncalves, Koopman-based lifting techniques for non-linear systems identification, IEEE Transactions on Automatic Control, in press.

# Dynamical systems on networks in cell proliferation modelling

**Aleksandra Puchalska**
University of Warsaw, Warsaw, Poland

Jacek Banasiak
University of Pretoria, Pretoria, South Africa
Łódź University of Technology, Łódź, Poland

In the talk we present two models on networks that discribe cell proliferation. The first is based on possibly infinite number of linear transport systems defined on metric graph coupled by bounded linear operator in vertices, see [1]. Using semigroup approach some assyptotic result which characterise the relation of the solution with linear ODE model is considered.

The second model is nonlinear, hybrid ODE-PDE system with transfer from edges defined by McKendrick boundary conditions. System can be considered as a generalisation of $M/M^B/1$ queuing model, or as a new attitude to modeling an acute leukemia, compare [2] or [3]. Using qualitative theory of nonlinear partial differential equations, some preliminary results on dynamics are stated.

The research is supported by National Science Center, Poland, grant number: 2017/25/N/ST1/00787.

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# A COPULA APPROACH TO CROSS-SHAREHOLDING NETWORKS

**Giulia Rotundo**
Sapienza University of Rome, Rome, Italy

Roy Cerqueti
Sapienza University of Rome, Rome, Italy

In this work, we focus on the cross-shareholding network and on ad-hoc indices of concentration and control. Starting from the empirical distribution, both marginal and joint, we propose a copula approach for scenario analysis under an eventual change of structure of dependence. The approach is alternative to massive computer simulation changing the links since each probability distribution may rise from many different configurations of the network. A further analysis explores the sensitivity of the results under perturbations of the marginals. The results point out the extremal configurations in an entropy-based context.

**REFERENCE**

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# Models of motion of substance in channels of networks with applications

**Nikolay K. Vitanov**
Bulgarian Academy of Sciences, Sofia, Bulgaria

Zlatinka I. Dimitrova
Bulgarian Academy of Sciences, Sofia, Bulgaria

We discuss flows of substance in channels that consist of nodes of network and edges which connect these nodes and form ways for motion of substance. Channels can have different number of arms and each arm can contain arbitrary number of nodes. We discuss first models for a channel that arms contain infinite number of nodes each. For stationary regime of motion of substance in such channels we obtain probability distributions connected to distribution of substance in any of channel's arms and in entire channel. Obtained distributions can be connected to Waring distribution. Next we discuss models for flow of substance in a channel that arms contain finite number of nodes each. We obtain probability distributions connected to distribution of substance in the nodes of the channel for stationary regime of flow of substance. We discuss applications of studied models to migration dynamics and transportation problems and calculate information measure and Shannon information measure for studied kind of flow of substance.

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