European Control Conference 2018, Limassol, Cyprus
Detailed Program of the Pre-Conference Workshop
"Recent Advances in Adaptive, Nonlinear and Networked Control. A Workshop on Occasion of Alexander Fradkov's 70th birthday"

Organizers:
Dr. Anton V. Proskurnikov, Prof. Emilia Fridman and Prof. Alexey Matveev

***Abstract*— This workshop is organized on the occasion of the 70th jubilee of Professor Alexander Fradkov's and aims to highlight the impact of his numerous contributions in the areas of adaptive and nonlinear control, control of networks, and the emerging area of cybernetical physics. This workshop brings together researchers who have collaborated with Alexander and will offer presentations on a broad range of up-to-date research in his primary fields of expertise, such as adaptive and speed-gradient control, dynamics of complex nonlinear systems and networks, control and observation under communication constraints, and application of control theory to natural sciences. Among the workshop's objectives, there is to promote the interest and awareness of the upcoming generation of researchers in these vibrant and diverse research areas.**

I. Introduction

In May 2018, Professor Alexander Lvovich Fradkov will celebrate his 70th birthday. To commemorate this event and honor his achievements in adaptive, nonlinear and networked control, we suggest to organize a full-day workshop.

Alexander Fradkov is the head of several bodies: the Theoretical Cybernetics Chair at the St. Petersburg State University, the Control of Complex Systems Laboratory at the Institute of Problems of Mechanical Engineering of the Russian Academy of Sciences, and the Complex Systems Chair at ITMO University. He is Post-President of International Physics and Control Society (IPACS) founded by him in 2003 and Vice-Chair of the IFAC Technical Committee on Adaptive and Learning Systems. Alexander Fradkov is a member of the European Control Association (EUCA) since 2014, member of the Russian National Committee on Automatic Control. In 2004, Alexander Fradkov has been elevated to IEEE Fellow *for contributions to adaptive and nonlinear systems*. He has been elected IFAC Fellow for the period 2014-2017 *for contributions to adaptive and nonlinear control theory and the deterministic approximation of stochastic systems*.

The contributions of Alexander Fradkov and his scientific school have had a great impact on the development of nonlinear and adaptive control and are extensively used by a broad research community. His has developed the general mathematical theory of energy control with applications to flight control, control of waves and vibrations, coordination and synchronization in complex large-scale systems such as power grids, coupled oscillators, quantum and particle ensembles and multispecies biological populations. He established passification criteria for linear and nonlinear systems based on the classical Kalman-Yakubovich-Popov (KYP) lemma. Alexander Fradkov has pioneered a novel area of *Cybernetical Physics*, studying physical systems on all levels by using methods of cybernetics (including systems, control, identification and information theories). His other fundamental contributions include extensions of Yakubovich's S-lemma, giving duality conditions in some non-convex optimization problems and necessity conditions in absolute stability criteria, as well as averaging techniques for control of stochastic systems and control under communication constraints.

The workshop brings together researchers who have collaborated with Prof. Fradkov in various years and will address a broad range of contemporary topics in the primary areas of his expertise, in particular, adaptive control, nonlinear control and control of networks, as well as relevant applications to natural sciences. An important goal of the workshop is to attract the attention of young researchers to these diverse research areas.

II. The list of invited lecturers and the workshop's agenda

The workshop's agenda includes two talks presented jointly by the organizers (A. Matveev, E. Fridman and A. Proskurnikov) and six talks to be presented by the following invited lecturers (names are in alphabetic order)

- **Prof. Frank Allgöwer**, University of Stuttgart, Stuttgart, Germany;
- **Prof. Boris Andrievsky**, Institute for Problems of Mechanical Engineering of the Russian Academy of Sciences (IPME RAS), St. Petersburg, Russia;
- **Dr. Denis Efimov**, INRIA Lille – Nord Europe, Lille, France;
- **Prof. Yuri Orlov**, Center for Scientific Research and Higher Education (CICESE), Ensenada, Mexico;

A.V. Proskurnikov is with Delft Center for Systems and Control, Delft University of Technology, The Netherlands. E-mail: anton.p.1982@ieee.org

E. Fridman is with School of Electrical Engineering, Tel-Aviv University, Tel Aviv, Israel. E-mail: emilia@eng.tau.ac.il

A. Matveev is with St. Petersburg State University, St. Petersburg, Russia. E-mail: almat1712@yahoo.com

- **Dr. Elena Panteley**, École Supérieure d'Electricité, Gif-sur-Yvette, France;
- **Dr. Dimitri Peaucelle**, LAAS-CNRS, Toulouse, France.

The workshop is opened by the lecture of Prof. F. Allgöwer (title and abstract to be announced later) and the brief talk by the organizers about Alexander Fradkov and his scientific school. The titles and abstracts of the remaining lectures are as follows.

A. Speed-gradient Principle: from classical control to the fundamental laws of Nature (Boris Andrievsky)

The Speed-gradient Principle (or SG-method) was originated by Alexander Fradkov in 1979 as a unified method of nonlinear and adaptive control systems design. Since then, it has been extensively developed and found applications in natural sciences and various fields of engineering. In this talk, we overview the foundations of the method and its applications to adaptive control, nonlinear control (including control of oscillation, chaos, resonance and synchronization), control of distributed systems and networks (including power networks), state and parameters estimation problems, broadband information transmission. Recent applications of the speed gradient principle in biology, medicine and physics will be also considered, in particular, control of periodic biological rhythms, control of multispecies ecological populations, control in quantum systems and dynamics of entropy in thermodynamical systems.

B. On Robust Stability of Multistable Systems (Denis Efimov)

Despite stability and robustness of dynamical systems with respect to a unique invariant set or equilibrium are well-developed theories, their extensions to multistable systems, i.e. the dynamics with several invariants like limit cycles or equilibria, are much more complicated and still under consideration. In this work one of such an extension dealing with input-to-state stability of multistable systems is described with application to robust synchronization of nonlinear oscillators and robust stability of systems regulated by the speed gradient algorithm.

C. Comprehending complexity: Data-rate constraints in large-scale networks (Alexey Matveev, Emilia Fridman, Anton V. Proskurnikov)

The joint talk by the workshop organizers presents the results obtained in collaboration with **Dr. Alexander Pogromsky** from Eindhoven University of Technology, Netherlands.

An essential focus in recent studies on control under communication constraints is on building a reliable real- time estimate of the state of a dynamical plant based on data received from sensors via a bit-rate constrained channel. One of the basic concerns here is about the minimal bitrate that is needed to build an efficient state estimate. As is now well known, this rate threshold is allied with the classic concept of the topological entropy (TE). Meanwhile, computation or even estimation of the TE of nonlinear systems has earned the reputation of an intricate matter; this intricacy briskly grows up with the system dimension. A series of the still rare examples of the closed-form computation and tight estimation of the minimal bit-rate, concerned with some prototypical nonlinear chaotic multi-dimensional systems, are offered in recent works by A. Matveev and A. Pogromsky and are based on a new common approach, exploiting a novel type of non-quadratic Lyapunov functions.

The objective of this talk is twofold. First, we are going to provide an overview of this approach. Second, the objective is to further extend its functionality via elaboration of a situation where the observed dynamics result from a feedback interconnection of finitely many subsystems with inputs and outputs. By following the lines of the celebrated small-gain theorem, where input-to-output stability of the system is guaranteed in terms of input-to- output features of the open-loop subsystems, a bit-rate of data transmission from the sensors to a remote observer sufficient for observability of the overall nonlinear plant is deduced from input-to-output characteristics of the subsystems and relations among them.

To illustrate utility of this development, we use it to prove a fact previously discovered via numerical studies for a few particular chaotic delayed systems: Their TE remains bounded as the delay grows without limits. We prove that this phenomenon is common and extends on the studied observability rates, and also offer explicit upper bounds on them that are uniform over all delays.

D. Adaptive control and identification of distributed parameter and time delay systems (Yuri Orlov)

Lyapunov redesign approach is developed side by side for distributed parameter and time delay systems. It is shown that if such a system is persistently excited by a sufficiently rich input, then unknown spatially-varying parameters of linear PDE's of parabolic, elliptic, and hyperbolic types are uniquely determined. In the case of linear time-delay systems, their weak controllability is shown to be necessary and sufficient condition of the identifiability of the unknown system parameters, including time-delay values. Multiple time-invariant commensurate and incommensurate delay values are admitted. Dynamic identifiers of the spatially distributed parameters as well as of the time delay systems are then constructed and utilized in the subsequent adaptive control synthesis of the systems in question. Numerical results support the effectiveness of the adaptive identifiers and controllers.

E. Dynamic consensus in heterogeneous networks (Elena Panteley)

In this talk we present a framework for the analysis of heterogeneous nonlinear systems, interconnected over networks described by directed graphs. Taken separately, network nodes may have different dynamical models or the same model with different parameters. Notion of dynamic consensus is introduce to handle the case when synchronized network has complex asymptotic behavior. We then characterize the network dynamics in terms of the stability properties of two interconnected systems that evolve in orthogonal spaces: one corresponding to the synchronization error dynamics

and the second, to the so-called emergent dynamics. Such an approach allows us to formulate conditions for practical asymptotic synchronization of heterogeneous networks and to characterize their collective behavior. We wrap up the talk with some examples and a short discussion on open problems.

F. From passivity-based adaptive control to LMI tuned adaptive control (Dimitri Peaucelle)

In the early 2000's we started a collaboration with A. L. Fradkov without really knowing each other. I was curious to know more from colleagues having worked with V.A. Yakubovich, especially on topics such as the S-procedure and the KYP lemma. But quite rapidly the discussions moved to the topic of adaptive control. My background was in robust control for linear systems by means of LMI methods and we decided to explore how such methods could apply to nonlinear adaptive control. This talk will present the path we followed: from initial results that assumed hyper-minimum-phase and passivity-type properties on systems, to LMI-based results that not only relax these strong assumptions but also provide numerical tools for the design of some of the many parameters involved in adaptive control laws. Results apply to linear systems and to linear systems with uncertainties. Examples of uncertain systems for which adaptation improves robustness compared to LTI control illustrate the effectiveness of our results.

III. Information about organizers and speakers

In this section we give short biographies of the invited lecturers and organizers (in alphabetic order).

Prof. Frank Allgöwer received the diploma in engineering cybernetics in 1987 and the doctoral degree in chemical engineering in 1996, both from the University of Stuttgart, Stuttgart, Germany. He is currently the Director of the Institute for Systems Theory and Automatic Control, University of Stuttgart. Prior to his present appointment he held a professorship in the electrical engineering department at ETH Zurich. He also held visiting positions at the California Institute of Technology, the NASA Ames Research Center, the DuPont Company and the University of California at Santa Barbara. Since 2012, he has been the Vice President of the German Research Foundation (DFG), Bonn, Germany.

Prof. Allgöwer is currently the President of the International Federation of Automatic Control (IFAC).

Prof. Boris Andrievsky received his Diploma degree (M.Sc.) in Electrical Engineering in 1972, Candidate of Sciences (Ph.D.) degree in Control Engineering in 1979 from the Baltic Stat Technical University, Saint Petersburg, and Doctor of Sciences (D.Sc.) degree in 2005 from the Institute for Problems of Mechanical Engineering of the Russian Academy of Sciences (IPME RAS). Since 1998 he has been with the IPME RAS, where he holds a position of Leading Research Fellow. Since 2010, he has also served as a Professor of the ITMO University in Saint Petersburg, and the Principal Research Fellow at Saint Petersburg State University. He had been Visiting Researcher at LAAS–CNRS, Toulouse, The University of Melbourne and Eindhoven University of Technology. He is an IEEE Senior Member, and a member of International Physics And Control Society (IPACS) and International Association "Academy of Navigation and Motion Control".

Dr. Denis Efimov received his Ph.D. degree in Automatic Control from the Saint-Petersburg State Electrical Engineering University (Russia) in 2001, and Dr.Sc. degree in Automatic control in 2006 from the Institute for Problems of Mechanical Engineering RAS (Saint-Petersburg, Russia). From 2000 to 2009 he was a research fellow at the Institute for Problems of Mechanical Engineering RAS, Control of Complex Systems Laboratory. From 2006 to 2011 he was working in the LSS (Supelec, France), the Montefiore Institute (University of Liege, Belgium) and the Automatic control group at the IMS laboratory (University of Bordeaux I, France). Since 2011, he is with INRIA (Non-A team at Lille - Nord Europe center). Dr. Efimov is a member of several IFAC TCs and Senior Member of IEEE.

Prof. Emilia Fridman received the M.Sc. degree from Kuibyshev State University, USSR, in 1981 and the Ph.D. degree from Voronezh State University, USSR, in 1986, all in mathematics. From 1986 to 1992 she was an Assistant and Associate Professor in the Department of Mathematics at Kuibyshev Institute of Railway Engineers, USSR. Since 1993 she has been with Tel Aviv University, where she is currently Professor of Electrical Engineering-Systems. She has held visiting positions at the Weierstrass Institute for Applied Analysis and Stochastics in Berlin (Germany), INRIA in Rocquencourt (France), Ecole Centrale de Lille (France), Valenciennes University (France), Leicester University (UK), Kent University (UK), CINVESTAV (Mexico), Zhejiang University (China), St. Petersburg IPM (Russia), Melbourne University (Australia), Supelec (France), KTH (Sweden). She serves/served as Associate Editor in Automatica, SIAM Journal on Control and Optimization and IMA Journal of Mathematical Control and Information.

Prof. Alexey Matveev was born in Leningrad, Russia, in 1954. He received the M.S. and Ph.D. degrees in Applied Mathematics and Control Engineering from the Leningrad University, Leningrad, Russia, in 1976 and 1980, respectively. Currently, he is a Professor with the Department of Mathematics and Mechanics, St. Petersburg State University, St. Petersburg, Russia. He has held visiting positions at the University of the Western Australia, Perth and the University of New South Wales, Sydney, Australia.

Prof. Yury Orlov received the M.Sc. degree from the Mechanical-Mathematical Faculty of Moscow State University, Moscow, Russia, in 1979, the Ph.D. degree in physics and mathematics from the Institute of Control Sciences-

Russian Academy of Sciences, Moscow, in 1984, and the D.Sc. degree in physics and mathematics from the Moscow Aviation Institute, Moscow, in 1990. He was with the Institute of Control Sciences of the Russian Academy of Sciences, Moscow, Russia, from 1979 to 1993. Since 1993, he is Full Professor with the Department of Electronics and Telecommunication, Scientific Research and Advanced Studies Center (CICESE), Ensenada, Mexico

Dr. Elena Panteley received the M.Sc. and Ph.D. degrees in applied mathematics from the State University of St. Petersburg, St. Petersburg, Russia, in 1986 and 1997, respectively. From 1986 to 1998, she held a research position with the Institute for Problem of Mechanical Engineering, Russian Academy of Science, St. Petersburg. Since 2004 she holds a tenure position as Senior Researcher of the French National Centre of Scientific Research (CNRS) at the Laboratoire de signaux et systemes, France. She is also associate researcher of ITMO University, St Petersburg, Russia, since 2014.

Dr. Dimitri Peaucelle was born in Leningrad, USSR, on March 02, 1974. He received the Ph.D. degree, in 2000, from Toulouse University, Toulouse, France. He is a Full-Time Researcher at the French National Center for Scientific Research (CNRS), working at LAAS in Toulouse, France. Dr. Peaucelle is an elected member of CNRS Section 7 that is in charge of evaluating CNRS activities in the field of information sciences. He is a member of several IFAC and IEEE-CSS Technical Committees. In 2017, he was the General Chair of IFAC World Congress.

Dr. Anton V. Proskurnikov received the M.Sc. and Ph.D. degrees from St. Petersburg State University, St. Petersburg, in 2003 and 2005 respectively. He was an Assistant Professor with St. Petersburg State University from 2003 to 2010. From 2014 to 2016, he was a Researcher with the Engineering and Technology Institute, University of Groningen, Groningen, The Netherlands. He also helds part-time research positions at the Institute for Problems of Mechanical Engineering of the Russian Academy of Sciences and ITMO University, St. Petersburg. He is currently a Researcher with the Delft Center for Systems and Control, Delft University of Technology, Delft, The Netherlands. Dr. Proskurnikov is a member of Editorial Board of the Journal of Mathematical Sociology.