



## Special issue dedicated to Prof. Alexander L. Fradkov

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## Special issue dedicated to Prof. Alexander L. Fradkov



This special issue is dedicated to Professor Alexander L'vovich Fradkov on the occasion of his 70th birthday that was celebrated in May 2018 and in recognition of his profound contributions to the interdisciplinary field of mathematical cybernetics.

Professor Fradkov is the head of Theoretical Cybernetics Chair at the St. Petersburg State University, the Control of Complex Systems Laboratory at the Institute for Problems in Mechanical Engineering of the Russian Academy of Sciences, and the Laboratory of Multi-Agent, Distributed and Networked Control Systems 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), EUROMECH and 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*. Scientific and organisational activities of Prof. Fradkov have, without exaggeration, built the bridge between Russian and international research communities working in the fields of systems, control and cybernetics.

Alexander Fradkov started his research career at the Department of Mathematics and Mechanics of Leningrad (now St. Petersburg) State University where he was working under the supervision of Prof. Vladimir A. Yakubovich, one of the founders of St. Petersburg scientific school on systems and control. In his master thesis defended in 1971, Alexander Fradkov obtained important results on duality in non-convex quadratic optimisation problems. In 1972–1989, Alexander Fradkov was staying with Leningrad Mechanical Institute (now Baltic State Technical University named after D.F. Ustinov), where he went the way from a Ph.D. student to full professor. In his

Ph.D. (1975) and habilitation (1986) theses, Prof. Fradkov has obtained several fundamental results concerned with adaptive control in linear and nonlinear systems, in particular, speed-gradient and passivity-based control algorithms. In 1990, Prof. Fradkov joined the Institute for Problems in Mechanical Engineering, where he founded the laboratory 'Control of Complex Systems'. From 1997, he has been with the Theoretical Cybernetics Chair at St. Petersburg State University that was headed by him in 2015. Since 2014, he is also with ITMO University. During his pedagogical career, he has supervised three habilitation ('doctor of science') and more than 20 Ph.D. theses, developed lecture courses on control of oscillation and chaos, cybernetical physics, mathematical modelling of cybernetical systems.

Alexander Fradkov has co-authored more than 700 works, including 12 monographs, 8 textbooks and 10 patents. He has also served as an editor of 19 monographs and paper collections, 5 special issues of international journals. 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. He has developed the general mathematical theory of energy control with applications to flight control, control of waves and vibrations, coordination and synchronisation 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 optimisation problems and necessity conditions in absolute stability criteria, as well as averaging techniques for control of stochastic systems and control under communication constraints.

The papers submitted to this special issue by colleagues of Prof. Fradkov are concerned with many of the aforementioned topics, as well as important practical applications. The special issue is divided into two parts.

### Part A: Frontiers of nonlinear, adaptive and networked control

- (1) A survey of novel kernel-based techniques for system identification is offered in the paper 'A shift in paradigm for system identification' by L. Ljung, T. Chen and B. Mu;
- (2) novel results on observer-based stabilisation of uncertain descriptor systems are obtained in the work 'An extended-observer approach to robust stabilisation of

- linear differential-algebraic systems' by A. Di Giorgio, A. Pietrabissa, F. Delli Priscoli and A. Isidori;
- (3) an alternative approach to stabilisation of uncertain descriptor systems based on direct adaptive control is proposed in the work 'Adaptive control design with S-variable LMI approach for robustness and  $L_2$  performance' by D. Peaucelle;
  - (4) a survey on feedback and feedforward control techniques for oscillation damping and noise rejection in linear systems is provided in the review paper 'On the use of Youla-Kucera parametrisation in adaptive active noise and vibration control – a review' by I.D. Landau;
  - (5) new results on observer-based stabilisation of broad class of uncertain systems with Lipschitz nonlinearities, polyharmonic disturbances and time-varying input delays are reported in the paper 'Robust predictive extended state observer for a class of nonlinear systems with time-varying input delay' by R. Sanz, P. García, E. Fridman and P. Albertos;
  - (6) a novel time-varying observer for time-varying systems with delayed measurements is proposed that exploits the properties of the system's observability Gramian is advocated in the work 'Gramian-based uniform convergent observer for stable LTV systems with delayed measurements' by J.G. Rueda-Escobedo, R. Ushirobira, D. Efimov and J.A. Moreno;
  - (7) the paper 'Sliding Sector Control Using New Equivalent Sector Control' by M. Iwase and K. Furuta advocates new methods of sliding-mode control, where the conventional sliding surface is replaced by a so-called sliding sector;
  - (8) another important aspect of sliding mode control – the possibility of event-triggered controller implementation – is addressed in the paper 'Event-triggered variable structure control' by M. Cucuzzella, G.P. Incremona and A. Ferrara;
  - (9) new results on the synchronisation in networks of heterogeneous oscillators are established in the manuscript 'Practical dynamic consensus of Stuart-Landau oscillators over heterogeneous networks' by E. Panteley, A. Loría and A. El-Ati;
  - (10) the experimental work 'Huygens' clocks: sympathy and resonance' by M. Francke, A. Pogromsky and H. Nijmeijer revises the well-known experiment on the clock synchronisation conducted by C. Huygens in the 17th century and reports new results on self-synchronisation in ensembles of coupled mechanical oscillators (metronomes).
- hysteresis ('jump resonance') are topics of the work 'Multi-jump resonance systems' by A. Buscarino, C. Famoso, L. Fortuna and M. Frasca;
- (2) an important problem of periodic motion generation and stabilisation in underactuated mechanical systems via the virtual constraint method is addressed in the work 'Model orbit output feedback tracking of underactuated mechanical systems with actuator dynamics' by L. Herrera, Y. Orlov, O. Montano and A. Shiriaev;
  - (3) an alternative bio-inspired approach to periodic motion generation in robot locomotion problems is offered in the paper 'Exploiting natural dynamics for gait generation in undulatory locomotion' by T. Ludeke and T. Iwasaki;
  - (4) novel distributed optimisation-based algorithms for traffic control in computer networks are reported in the paper 'Necessary and sufficient condition for non-concave network utility maximisation' by J. Wang, J. Guo, Q. Wang, Z. Duan and G. Chen;
  - (5) a new  $H_2/H_\infty$  control design method to increase the efficiency of an underground coal gasification process is reported in the work 'Robust multi-objective control design for underground coal gasification energy conversion process' by A.M. Chaudhry, A.A. Uppal, Y.M. Alsmadi, A.I. Bhatti and V.I. Utkin;
  - (6) mathematical models of heat and electricity co-generation and relevant Lyapunov-based control algorithms are examined in the paper 'Controlling co-generation: conservation laws, modelling and Lyapunov synthesis' by D. Danciu and V. Räsvan;
  - (7) sliding-mode control algorithms for frequency control of power grids are reported in the work 'Robust load frequency control of nonlinear power networks' by S. Trip, M. Cucuzzella, C. De Persis, A. Ferrara and J.M.A. Scherpen.

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## Part B: Applications

- (1) Analysis and design of nonlinear circuits with 'pathological' frequency response, featured by one or several zones of