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OF AUTOMATIC CONTROL

17th IFAC Workshop on Control Applications of Optimization (CAO 2018)

Book of Abstracts and Program

Yekaterinburg, Russia,
October 15–19, 2018

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http://www.imm.uran.ru

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WELCOME FROM IPC AND NOC CHAIRS

It is our pleasure to welcome you to the 17th IFAC Workshop on Control Applications of Optimization (CAO 2018). CAO 2018 will be held in Yekaterinburg, Russia, during October 15–19, 2018.

CAO 2018 is the serial 17th workshop of the IFAC Technical Committee on Optimal Control (TC 2.4). It is aimed at overviewing the latest advantages in the theory of optimal control, especially, in the field of applications of new methods and numerical algorithms to solving problems in industry, robotics, mechatronics, power and energy systems, economics, finance and ecology. It will give an opportunity to specialists in optimal control, differential games and optimization to share their experience with practitioners, discuss new arising problems, outline scientific and commercial applications, and describe new research directions.

One of the goals of the workshop is to bring together researchers and engineers, applied economists and environmental scientists, and to give an up to date view of the major applications of optimization for control purposes and for decision making in economy and industry.

Working language of the Workshop is English. The program of the Workshop will include 60-minute invited lectures and 20-minute regular talks.

Topics

- optimization methods
- optimal control
- differential games
- evolutionary algorithms
- stochastic optimization
- numerical methods for optimization
- optimization under uncertainties including the theory of noise measurements
- multi-objective control and optimization
- robust control and stabilization
- applications in economics, management and environmental science
- generalized solutions of Hamilton—Jacobi equations
- control of partial differential equations
- real-time control problems
- control design for hybrid systems
- large scale optimization problems
- singularities in optimization.

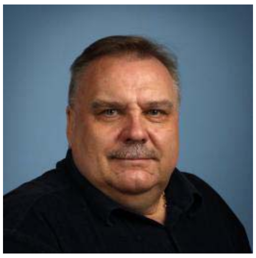
With about 190 papers submitted by authors coming from more than 24 countries, CAO 2018 confirms as a relevant event within IFAC. About 400 reviewers have been involved in the technical assessment of the submitted papers. As a result, about 550 reviews were received, which led to the acceptance of 166 papers constituting the final program of CAO 2018. The CAO 2018 program will consist of plenary lectures and parallel regular sessions. Besides, the CAO 2018 is complemented with a social and cultural program to enjoy Yekaterinburg and Urals.

We look forward to welcoming you in Yekaterinburg!

IPC CHAIRS

Stefan Pickl

Alexander Tarasyev



NOC CHAIRS

Alexander Kurzhanski

Nikolay Lukoyanov

SPECIAL SEMINARS

Optimal Control in Modeling Economic Processes and Environmental Systems

Prof. Marina Medvedeva, Ural Federal University named after the first President of Russia B.N. Yeltsin, Yekaterinburg, Russia, urfu.ru,
Prof. Sergey Mitsek, Liberal Arts University, Yekaterinburg, Russia, gu-ural.ru,
Prof. Tapio Palokangas, University of Helsinki, HECER, Finland, tuhat.helsinki.fi

Abstract: Nowadays, applications of optimal control to modeling economic systems and environmental systems have become an indispensable tool for effective research in economics, management and environmental science. The integrating framework of the seminar is dynamic systems theory, which offers a common basis for multidisciplinary research and mathematical tools for solving complicated models, leading to new insights in economic and environmental issues. Particularly, participants discuss methods of optimal control, optimization, and dynamic games in combination with econometric techniques. Special attention is paid to economic growth models, investment effectiveness and management of financial flows, human capital, optimization of energy infrastructure, transport routes optimization, assessment of labor market and labor migration, cooperative behavior of economic agents, optimization of information resources, tax scaling, economic and environmental forecasting. The seminar aims to provide a forum for presenting innovations and new results on control algorithms for optimization of economic and environmental systems, to discuss the advantages, challenges and work to do in this interesting and promising research area.

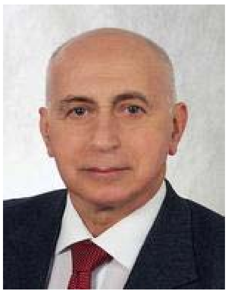
Construction of Attainability Sets, Trajectory Tubes, Value Functions and Optimal Feedbacks

Prof. Sergey Aseev, Steklov Mathematical Institute, Moscow, Russia, www.mi-ras.ru,
Prof. Yurii Ledyaev, Western Michigan University, Kalamazoo, USA, www.wmich.edu,
Prof. Vladimir Ushakov, Krasovskii Institute of Mathematics and Mechanics, Yekaterinburg, Russia, www.imm.uran.ru

Abstract: The seminar scope is devoted to contemporary methods of dynamic optimization and applications to solution of optimal control problems in science and technology. It addresses issues of optimal control construction and elaboration of feedbacks basing on analysis of Hamiltonian systems arising via necessary and sufficient optimality conditions. The seminar studies tools of the Pontryagin maximum principle, specifically, for the class of infinite-horizon optimal control problems arising in economic growth modeling. A special attention is paid to problems of designing algorithms for numerical construction of attainability sets, trajectory tubes, value functions and optimal feedbacks, including program-predictive feedbacks. Particular interest is connected with the problem of construction of optimal solutions in differential games, especially with application of advanced tools of optimal control theory and the theory of generalized (minimax, viscosity) solutions of Hamilton—Jacobi equations. An important question for discussion is construction and modeling of dynamic equilibrium solutions, shifting system's trajectories to sustainable domains. An essential part of the session agenda is devoted to application and adequateness of game-theoretical constructions to model processes in engineering, economics and finance.

PLENARIES

Plenary Talk – Monday, 15 October, 2018, 11:00–12:00



Felix L. Chernousko*, Professor, Dr., Academician of RAS,*

Ishlinsky Institute for Problems in Mechanics of the Russian Academy of Sciences, Moscow, Russia

Optimal Motions of Bodies Controlled by Internal Moving Masses

Locomotion of robots in a resistive medium can be based on special motions of auxiliary internal masses inside the main body of the robot. This locomotion principle is used in micro-robots and vibro-robots moving in tubes. In the paper, optimal motions of systems controlled by internal moving masses are considered. One-dimensional optimal motions are examined for systems moving in media in the presence of external resistance, including dry friction and resistant forces depending on the velocity of the moving body. Two-dimensional motions are considered for bodies subject to dry friction and containing internal moving masses. Optimal motions of a two-body system are obtained for the case where external forces are negligible. This situation is a model for the re-orientation of a spacecraft containing a moving internal mass.

Plenary Talk – Monday, 15 October, 2018, 12:00–13:00

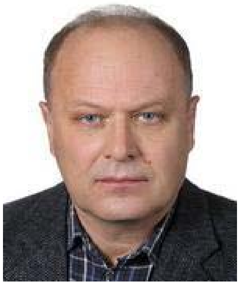
Marc Quincampoix*, Professor, Dr.,*

Laboratoire de Mathématiques de Bretagne Atlantique (CNRS UMR 6205), Université de Brest, France

Probabilistic Uncertainty in Differential Games and Control

In classical optimal control and in differential games, the controllers are supposed to a have a perfect knowledge of the dynamics, of the payoffs and of the initial conditions of the system. However in several practical situations only partial informations on these data are available. The most simple example is a control system with a given terminal payoff where the initial condition is not perfectly known: only a probabilistic information is known (for instance, the initial condition lies in a given ball with a uniform probability measure). The initial condition is then replaced by a probability measure which “propagates” according to the control system. One can be interested to characterize the optimal mean value of the cost. We will show that this value function — which depends on the initial probability measure — could be characterized as the unique solution — in a suitable sense — of a Hamilton—Jacobi—Bellmann equation stated on the space of probability measures. This brings some technical difficulties where the optimal transport theory is an important tool.

Plenary Talk – Tuesday, 16 October, 2018, 09:30–10:30

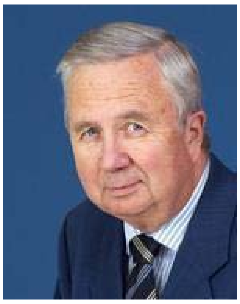


Sergey M. Aseev*, Professor, Dr., Corresponding Member of RAS,*
Steklov Mathematical Institute of the Russian Academy of Sciences, Moscow, Russia, and International Institute for Applied Systems Analysis, Laxenburg, Austria

Infinite-Horizon Optimal Control. Some Recent Advances and Applications in Economic Growth Theory

Infinite-horizon optimal control problems naturally arise in studying different models of optimal dynamic allocation of economic resources, in particular, in growth theory. Typically, the initial state is fixed and the terminal state (at infinity) is free in such problems, while the utility functional to be maximized is given by an improper integral on the time interval $[0,\infty)$. Although the state at infinity is not constrained the maximum principle for such problems may not hold in the normal form, and the standard transversality conditions at infinity may fail. Additional difficulties arise when the model involves a natural resource (renewable or not renewable) as an essential factor of production. In this case, typically, admissible controls are only bounded in an integral sense, which precludes the direct application of the standard existence results. The talk is devoted to some recent results in this field of optimal control and their applications in growth theory.

Plenary Talk – Wednesday, 17 October, 2018, 09:30–10:30



Alexander B. Kurzhanski*, Professor, Dr., Academician of RAS,*
Lomonosov Moscow State University, Moscow, Russia

The Theory of Group Control: a Road Map

The presentation deals with description of feedback control strategies for a group of systems involved in jointly solving the problem of reaching a given target set under stationary or moving obstacles while ensuring collision avoidance among the members of the group. The feedback nature of the overall solutions also requires to solve an array of subproblems of on-line group observations. Finally described is the total procedure of optimalizing such controlled processes.

PROGRAM AT A GLANCE

CAO 2018 Technical Program Monday October 15, 2018

Track 1	Track 2	Track 3
	09:30-10:30 MoOpnUr *Cultural Center "Ural"* **Opening**	
	11:00-13:00 MoP1Ur *Cultural Center "Ural"* **Plenary Session 1**	
15:00-16:20 MoR1A *Hotel Hall A* **Optimal Control I**	15:00-16:20 MoR1B *Hotel Hall B* **Robust Control and Stabilization I**	15:00-16:20 MoR1V *Hotel VIP-Hall* **Applications in Economics, Management and Environmental Science I**
16:40-18:00 MoR2A *Hotel Hall A* **Optimal Control II**	16:40-18:00 MoR2B *Hotel Hall B* **Robust Control and Stabilization II**	16:40-18:00 MoR2V *Hotel VIP-Hall* **Applications in Economics, Management and Environmental Science II**

CAO 2018 Technical Program Tuesday October 16, 2018

Track 1	Track 2	Track 3
	09:30-10:30 TuP2IMM *Krasovskii Institute Hall* **Plenary Session 2**	
11:00-12:20 TuR1A *Hotel Hall A* **Real-Time Control Problems I**	11:00-12:20 TuR1B *Hotel Hall B* **Robust Control and Stabilization III**	11:00-12:20 TuR1V *Hotel VIP-Hall* **Numerical Methods for Optimization I**
14:20-15:40 TuR2A *Hotel Hall A* **Optimal Control III**	14:20-15:40 TuR2B *Hotel Hall B* **Differential Games I**	14:20-15:00 TuTCV *Hotel VIP-Hall* **TC 2.4 Meeting**
16:10-17:50 TuR3A *Hotel Hall A* **Optimal Control IV**	16:10-17:50 TuR3B *Hotel Hall B* **Differential Games II**	

CAO 2018 Technical Program Wednesday October 17, 2018

Track 1	Track 2	Track 3
	09:30-10:30 WeP3IMM *Krasovskii Institute Hall* **Plenary Session 3**	
11:00-12:20 WeR1A *Hotel Hall A* **Optimal Control V**	11:00-12:20 WeR1B *Hotel Hall B* **Control Design for Hybrid Systems**	11:00-12:20 WeR1V *Hotel VIP-Hall* **Numerical Methods for Optimization II**
14:20-15:40 WeR2A *Hotel Hall A* **Real-Time Control Problems II**	14:20-15:40 WeR2B *Hotel Hall B* **Optimization Methods I**	14:20-15:40 WeR2V *Hotel VIP-Hall* **Applications in Economics, Management and Environmental Science III**
16:10-17:50 WeR3A *Hotel Hall A* **Real-Time Control Problems III**	16:10-17:50 WeR3B *Hotel Hall B* **Optimization Methods II**	16:10-17:50 WeR3V *Hotel VIP-Hall* **Applications in Economics, Management and Environmental Science IV**

CAO 2018 Technical Program Thursday October 18, 2018

Track 1	Track 2	Track 3
09:30-10:50 ThR1A *Hotel Hall A* **Differential Games and Control Problems with Uncertainties**	09:30-10:50 ThR1B *Hotel Hall B* **Multi-Objective Control and Optimization I**	09:30-10:50 ThR1V *Hotel VIP-Hall* **Stochastic Optimization I**
11:20-12:40 ThR2A *Hotel Hall A* **Control Algorithms**	11:20-12:40 ThR2B *Hotel Hall B* **Multi-Objective Control and Optimization II**	11:20-12:40 ThR2V *Hotel VIP-Hall* **Stochastic Optimization II**
14:20-15:40 ThR3A *Hotel Hall A* **Optimal Control VI**	14:20-15:40 ThR3B *Hotel Hall B* **Optimization under Uncertainties Including the Theory of Noise Measurements I**	14:20-15:40 ThR3V *Hotel VIP-Hall* **Control of Partial Differential Equations I**
16:10-17:50 ThR4A *Hotel Hall A* **Optimal Control VII**	16:10-17:50 ThR4B *Hotel Hall B* **Optimization under Uncertainties Including the Theory of Noise Measurements II**	16:10-17:50 ThR4V *Hotel VIP-Hall* **Control of Partial Differential Equations II**

CAO 2018 Technical Program Friday October 19, 2018

Track 1	Track 2	Track 3
09:30-10:50 FrR1A *Hotel Hall A* **Optimization Methods III**	09:30-10:50 FrR1B *Hotel Hall B* **Generalized Solutions of Hamilton—Jacobi Equations I**	09:30-10:50 FrR1V *Hotel VIP-Hall* **Robust Control and Stabilization IV**
11:20-12:40 FrR2A *Hotel Hall A* **Optimization Methods IV**	11:20-12:40 FrR2B *Hotel Hall B* **Generalized Solutions of Hamilton—Jacobi Equations II**	11:20-12:40 FrR2V *Hotel VIP-Hall* **Numerical Methods for Optimization III**

14:20-15:00 FrClsCls *Hotel Hall A* **Closing**

BOOK OF ABSTRACTS

of 17th IFAC Workshop on Control Applications of Optimization

Technical Program for Monday October 15, 2018

MoP1Ur Cultural Center "Ural"

Plenary Session 1 (Plenary Session)

Chair: Kurzhanski, Alexander B. — Lomonosov Moscow State University

Co-Chair: Subbotina, Nina — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

11:00-12:00 MoP1Ur.1

Optimal Motions of Bodies Controlled by Internal Moving Masses, pp. 1-6

Chernousko, Felix L. — Ishlinsky Inst. for Problems in Mechanics, RAS

Locomotion of robots in a resistive medium can be based on special motions of auxiliary internal masses inside the main body of the robot. This locomotion principle is used in micro-robots and vibro-robots moving in tubes. In the paper, optimal motions of systems controlled by internal moving masses are considered. One-dimensional optimal motions are examined for systems moving in the presence of dry friction forces. Two-dimensional motions are considered for bodies subject to dry friction and containing internal moving masses. Optimal motions of a two-body system are obtained for the case where external forces are negligible. This situation is a model for the re-orientation of a spacecraft containing a moving internal mass.

12:00-13:00 MoP1Ur.2

Probabilistic Uncertainty in Differential Games and Control

Quincampoix, Marc — Univ. De Brest, France

In classical optimal control and in differential games, the controllers are supposed to a have a perfect knowledge of the dynamics, of the payoffs and of the initial conditions of the system. However in several practical situations only partial informations on these data are available. The most simple example is a control system with a given terminal payoff where the initial condition is not perfectly known: only a probabilistic information is known (for instance, the initial condition lies in a given ball with a uniform probability measure). The initial condition is then replaced by a probability measure which "propagates" according to the control system. One can be interested to characterize the optimal mean value of the cost. We will show that this value function — which depends on the initial probability measure — could be characterized as the unique solution — in a suitable sense — of a Hamilton—Jacobi—Bellmann equation stated on the space of probability measures. This brings some technical difficulties where the optimal transport theory is an important tool.

MoR1A Hotel Hall A

Optimal Control I (Regular Session)

Chair: Tarasyev, Alexander M. — Krasovskii Inst. of Mathematics and Mechanics of Ural Branch of RAS, Ural Federal Univ

Co-Chair: Ivanov, Grigorii — Moscow Inst. of Physics and Tech

15:00-15:20 MoR1A.1

Robust Methods for Stabilization of Hamiltonian Systems in Economic Growth Models, pp. 7-12

Usova, Anastasiia — Univ. of Western Ontario

Tarasyev, Alexander M. — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The paper discusses the existence of a linear manifold in a vicinity of a steady state for stabilization of the Hamiltonian systems arising in optimal control problems for economic growth models. It is shown that such stable manifold exists for almost all possible values of model parameters guaranteeing the existence of a steady state. Research is based on the qualitative analysis of the Hamiltonian dynamics, which plays a key role for investigating the asymptotic behaviour of optimal trajectories. A procedure is proposed for stabilization of the Hamiltonian system, whose trajectories converge to equilibrium and approximate the optimal solution with the quadratic accuracy at a vicinity of the steady state. Basing on properties of the Hamiltonian matrices, the classification of steady states is provided and the sensitivity analysis for identification of their character is implemented with respect to model parameters. The proposed approach is applied to the model dealing with dynamic optimization of the resource productivity.

15:20-15:40 MoR1A.2

Strong and Weak Convexity in Nonlinear Differential Games, pp. 13-18

Ivanov, Grigorii — Moscow Inst. of Physics and Tech

Golubev, Maxim — Moscow Inst. of Physics and Tech. (State Univ)

We obtain sufficient conditions for the values of the Minkowski operators to be weakly convex and smooth. These operators play the same role in nonlinear differential games as the Minkowski sum and the Minkowski difference do in linear differential games: they are basic operators in algorithms of computing reachable sets and optimal strategies. We also prove that the signed distance to convex sets is a Lipschitz continuous function of the set with respect to the Hausdorff distance.

15:40-16:00 MoR1A.3

Solution of Discontinuous Problem of Optimal Control Over the Individual Human Capital Development by the Numerical Method, pp. 19-24

Bolodurina, Irina — Orenburg State Univ

Parfenov, Denis — Orenburg State Univ

Ansiferova, Larisa — Orenburg State Univ

The optimal control problem is studied, which was described by a dynamical system with a nonsmooth right-hand side, using the example of the problem of managing the development of individual human capital. Specialized methods of searching for optimal control are developed, focused on accounting for the violation of the smoothness of the right-hand side of the dynamical system under consideration. Necessary optimality conditions are obtained in the form of Pontryagin's maximum principle with additional jump conditions for conjugate functions. Numerical methods have been developed to solve the nonsmooth task of managing the development of human capital, making it possible to find optimal control and give it a meaningful interpretation.

16:00-16:20 MoR1A.4

Psi_0 Vector Reachability Domain Determination Approach for Solving Control Problems Using the Maximum Principle, pp. 25-27

Danilova, Svetlana — V.A. Trapeznikov Inst. of Control Sciences of Russian Acad Sci

An approach is proposed to determine the reachability region of the Psi_0 vector. It will significantly speed up the solution of optimal control problems using the maximum principle for multidimensional dynamic objects.

MoR1B	Hotel Hall B
Robust Control and Stabilization I (Regular Session)	

Chair: Andreev, Aleksandr	Ulyanovsk State Univ
Co-Chair: Popova, Svetlana Nikolaevna	Udmurt State Univ

15:00-15:20 MoR1B.1

On Global Trajectory Tracking Control of Robot Manipulators with Flexible Joints, pp. 28-33

Andreev, Aleksandr	Ulyanovsk State Univ
Peregudova, Olga	Ulyanovsk State Univ
Sobolev, Aleksei	Ulyanovsk State Univ

In this paper a novel approach to the global trajectory tracking control problem for manipulators with flexible joints is presented. The dynamic model of such mechanical systems has a cascade structure that allows to decouple the links dynamics from the actuators ones. We propose a design procedure for nonlinear controller with computed feedforward of robot manipulators with revolute joints in a cylindrical phase space. Stability proof of the closed-loop system is given by constructing a Lyapunov function which is periodic on angular coordinates. We illustrate the implementation of the controller using simulation example.

15:20-15:40 MoR1B.2

Robust Disturbance Rejection by the Attractive Ellipsoid Method Part I: Continuous-Time Systems, pp. 34-39

García González, Pablo Josué	CINVESTAV-IPN, México
Ampountolas, Konstantinos	Univ. of Glasgow

This paper develops sufficient conditions for the constrained robust stabilization of continuous-time polytopic linear systems with unknown but bounded perturbations. The attractive ellipsoid method (AEM) is employed to determine a robustly controllable invariant set, known as attractive ellipsoid, such that the state trajectories of the system asymptotically converge to a small neighborhood of the origin despite the presence of non-vanishing perturbations. To solve the stabilization problem, we employ the Finsler's lemma and derive new linear matrix inequality (LMI) conditions for robust state-feedback control design, ensuring convergence of state trajectories of the system to a minimal size ellipsoidal set. We also consider the state and control constrained problem and derive extended LMI conditions. Under certain conditions, the obtained LMIs guarantee that the attractive ellipsoid is nested inside the bigger ellipsoids imposed by the control and state constraints. Finally, we extend our AEM approach to the gain-scheduled state-feedback control problem, where the scheduling parameters governing the time-variant system are unknown in advance but can be measured in real-time. Two examples demonstrate the feasibility of the proposed AEM and its improvements over previous works.

15:40-16:00 MoR1B.3

Assignability of Certain Lyapunov Invariants for Linear Discrete-Time Systems, pp. 40-45

Popova, Svetlana Nikolaevna	Udmurt State Univ

We prove that the property of uniform complete controllability is sufficient for the simultaneous proportional local assignability of the Lyapunov spectrum and the Lyapunov irregularity coefficient for linear control systems with discrete time.

16:00-16:20 MoR1B.4

Control of Plane Motions of a Helicopter with Cargo on the Basis of the Double Pendulum Model, pp. 46-50

Bezglasnyi, Sergey P.	Samara State Aerospace Univ

The problem of constructing asymptotically stable program motions of the double pendulum with variable length and movable pivot is solved. This program motions are given arbitrarily. The solution is obtained by synthesis of the active program control applied to the system of bodies. Also, it's obtained by the synthesis of the stabilizing control based on the feedback principle. The control is constructed in the form of an exact analytic solution in the class of continuous functions. The problem is solved based on the direct Lyapunov method of stability theory. The Lyapunov's function with sign-constant derivative is used.

MoR1V	Hotel VIP-Hall
Applications in Economics, Management and Environmental Science I (Regular Session)	

Chair: Berg, Dmitry	Urals Federal Univ. and Inst. of Industrial Ec. UB RAS
Co-Chair: Dorofeyuk, Yulia	Insitute of Control Sciences of RAS

15:00-15:20 MoR1V.1

Structural Correction Method for Monitoring Parameter Estimation in the Unrepresentative Sample Analysis Problem, pp. 51-54

Dorofeyuk, Yulia	Insitute of Control Sciences of RAS
Dorofeyuk, Alexander	Insitute of Control Sciences of RAS
Chernyavskiy, Alexandr	Inst. of Control Sciense

One of the key issues of the selective statistical investigations (monitoring) analysis problem in case of small samples is insufficient representativeness of the monitoring parameters, especially in the context of selective statistical data generation. In the paper, the structural-classification correction method of monitoring parameter estimation is proposed. The new method allows increasing the reliability of indices estimates, which is critical for largescale socio-economic system analysis and control problems. Developed method applied for economic activity rates analysis problem.

15:20-15:40 MoR1V.2

Optimization of Sentiment Analysis Methods for Classifying Text Comments of Bank Customers, pp. 55-60

Lutfullaeva, Malika	Ural Federal Univ
Medvedeva, Marina	Ural Federal Univ
Komotskiy, Eugene	Ural Federal Univ
Spasov, Kamen	Sofia Univ. “St.Kliment Ohridski”

A method of sentiment analysis of the text and its approbation in solving the problem of analysis of text comments left by the Bank's customers are performed. The proposed method consists in a combination of three approaches: rules-based, dictionaries and machine learning with a teacher. New method of text vectorization-tonal vectorization instead of classical ones, such as “bag-of-words” and TF-IDF, is proposed. The text was classified by logistic regression with regularization. A series of experiments were carried out and the optimal value of the regularization parameter was found in terms of classification accuracy.

15:40-16:00 MoR1V.3

Modeling of the Municipality Entrepreneurial Community Functioning Using the Methods of System Dynamics, pp. 61-66

Berg, Dmitry	Urals Federal Univ. and Inst. of Industrial Ec. UB RAS
Kolomytseva, Anna	Donetsk National Tech. Univ
Apanasenko, Anastasiya	Ural Federal Univ. Named after the First President of Russia
Isaichik, Ksenia	Ural Federal Univ. Named after the First President of Russia

The objective of this research is a development of the municipality entrepreneurial network functioning system-dynamic simulation model. Model has been implemented in Powersim Studio 7 simulation modeling environment on experimental level. It allows monitoring the state of communications and exchange for various periods of time on the one hand, as well as establishing the architecture of links, levels and exchange flows between members of the network with the most effective conditions for the realization of commodity and money relations inside and outside the network on the other. Inject of inside money in entrepreneurial network is considered to be a method of increasing exchange effectiveness. Parameter that reflects its usage is a main regulator for exchange and a control model parameter. Simulation experiments result, expressed in resulting coefficients (liquidity, cooperation, exchange synchronization), allows to numerically assess the system state at different control parameter values. It makes the designed model an effective support tool for optimization decisions and administrating of a complicate economic system, like municipality entrepreneurial network.

16:00-16:20 MoR1V.4

Optimization of Information Resources in the Industrial Ecology, pp. 67-72

Tarasyev, Alexander M. — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Ford, Vitaly — Arcadia Univ
Turygina, Victoria — Ural Federal Univ
Dolganov, Aleksey — Ural Federal Univ

An important task in business of any enterprise and, in particular, enterprises working in the industrial ecology is the timely transmission of data and relevant information. The article provides an overview and analysis of technologies of employee notification about any type of events. The model of optimization of data transmission over messengers is given. Today, there are a huge number of different applications for instant messaging: from ordinary messengers to social networks with built-in messaging modules. Among the usual messengers can be identified such as WhatsApp, Viber, Skype, Snapchat, KakaoTalk and others. Social network messengers include such examples as Vkontakte, Facebook, Instagram, etc. The special optimization model has been developed for enterprises operating in the industrial ecology which allows to manage the notifications and alerts of employees involved in specific business processes.

MoR2A — Hotel Hall A

Optimal Control II (Regular Session)

Chair: Tenno, Robert — Aalto Univ. School of Electrical Engineering
Co-Chair: Ovseevich, Alexander — Inst. for Problems in Mechanics, Russian Ac. Sci

16:40-17:00 MoR2A.1

Boundary Control of Reacting Species in Semi-Infinite and Finite Diffusion Processes, pp. 73-78

Tenno, Robert — Aalto Univ. School of Electrical Engineering

Boundary control of oxidizing species at the cathode surface is considered in an electrochemical system, which is the plant of two electrodes and plant of three electrodes submerged in the stirred and unstirred electrolytes. The exact feedforward controls are found using ideas of motion planning, Laplace transform and other techniques that in the end solve the inverse problem for the given time-variable reference of species at the cathode surface. The uncertainty of surface reaction existing in the system is suppressed with two modifications of controls. In the first case, the feedforward control is extended with a PI feedback that uses measured in the process electric current passing through the system. In the second case, an adaptive feedforward control is established for the case when the exchange current density is unknown drifting parameter and is estimated as it changes using a conditionally Gaussian filter. In both cases, the process control is simulated and revealed to be effective.

17:00-17:20 MoR2A.2

Optimal Taxation with Fertility and Welfare-Damaging Emissions, pp. 79-83

Palokangas, Tapio — Univ. of Helsinki

Output is produced from labor and capital by technologies that differ in their emission intensity and relative capital intensity. Aggregate emissions decrease every individual's health, but each individual can invest its own health. Population grows by the difference of fertility and exogenous mortality. Labor is used in production or child rearing. I construct a differential game where the benevolent government is a leader that determines taxes and subsidies, while the representative family is a follower that saves in capital and decides on its number of children. The main results are as follows. Without government intervention, population increases or decreases indefinitely. Capital should be taxed, if dirty technology, and subsidized, if clean technology is relatively capital intensive. Child rearing should be taxed, if dirty technology is relatively capital intensive or mildly labor intensive.

17:20-17:40 MoR2A.3

Rotation of a Body by an Internal Mass, pp. 84-86

Shmatkov, Anton — Ishlinsky Inst. for Problems in Mechanics RAS
Chernousko, Felix L. — Ishlinsky Inst. for Problems in Mechanics, RAS

We considered a mechanical system consisting from a massive rigid body and a small point mass. This system can move only under the influence of the internal forces. Only plane movements are allowed. The problem is to rotate the rigid body to the specific angle in the shortest time changing the position of the point mass. We found both suboptimal and exact analytical solutions. When the mass of the point is much smaller in comparison with the mass of the body the optimal point trajectory in the coordinates system moving with the body is close to the arc of a circle. We obtained the analytical expressions for the accuracy of such an approximation.

17:40-18:00 MoR2A.4

Asymptotically Optimal Dry-Friction Like Control for a Simplest Distributed System, pp. 87-92

Ovseevich, Alexander — Inst. for Problems in Mechanics, Russian Ac. Sci
Fedorov, Aleksy — Russian Quantum Center

In the present work, we develop an asymptotical control theory for a closed string under a bounded load applied to a single distinguished point. We find and describe exact classes of the string states that allows complete damping, and asymptotically exact value of the required time. We design a dry-friction like feedback control, which turns out to be asymptotically optimal. We also explicitly describe the singular arcs of the control. The central result is a proof of asymptotic optimality of the control thus constructed.

MoR2B — Hotel Hall B

Robust Control and Stabilization II (Regular Session)

Chair: Ampountolas, Konstantinos — Univ. of Glasgow
Co-Chair: Zhou, Li — Sichuan Univ

16:40-17:00 MoR2B.1

Robust Disturbance Rejection by the Attractive Ellipsoid Method Part II: Discrete-Time Systems, pp. 93-98

García González, Pablo Josué — CINVESTAV-IPN, México
Ampountolas, Konstantinos — Univ. of Glasgow

This paper presents sufficient conditions for the robust stabilization of discrete-time polytopic systems subject to control constraints and unknown but bounded perturbations. The attractive ellipsoid method (AEM) is extended and applied to cope with this problem. To tackle the stabilization problem, new linear matrix inequality (LMI) conditions for robust state-feedback control are developed. These conditions ensure the convergence of state trajectories of the system to a minimal size ellipsoidal set despite the presence of non-vanishing disturbances. The developed LMI conditions for the AEM are extended to deal with the problem of gain-scheduled state-feedback control, where the scheduling parameters governing the time-variant dynamical system are unknown in advance but can be measured in real-time. A feature of the obtained conditions is that the state-space matrices and Lyapunov matrix are separated. The desired robust control laws are obtained by convex optimization. Numerical simulations are given to illustrate the feasibility of the proposed AEM for robust disturbance rejection.

17:00-17:20 MoR2B.2

Quality Stability Evaluation Model Based on Intelligent Control, pp. 99-104

Ji, Haorui — Beijing Univ. of Posts and Telecommunication
Liu, Manhao — Beijing Univ. of Posts and Telecommunication
He, Ge — Sichuan Univ
Zhou, Li — Sichuan Univ
Du, Yu — Sichuan Univ

At present, statistical process control in process industry is mainly off-line, which is incompetence in handling problems such as process control deviations and quality instability. In this work, an intelligent process control methodology is proposed for the on-line quality evaluation, by using GA-BP hybrid algorithm. Given that fact that the practical applications in industries are usually muti-objective, the multi-output neural network model is studied in order to compensate the deficiency of the single-output GA-BP algorithm. The proposed methodology was applied to a real operation unit to illustrate its effectiveness and feasibility. In the case study, two quality indicators were chosen as online evaluation objectives of the chosen operation unit. The algorithm was constructed, with 12 nodes in the input layer and 2 nodes in the output layer, which is then trained by 800 groups of real-time data and validated by 200 groups of test data.

17:20-17:40 MoR2B.3

Stabilization of Some Systems with Constant Delay, pp. 105-109

Grebenshchikov, Boris — Ural Federal Univ
Lozhnikov, Andrey — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

An algorithm for stabilization of a class of systems with constant delay is proposed.

17:40-18:00 MoR2B.4

Uniformly Consistent Linear Discrete-Time Systems with Incomplete Feedback, pp. 110-114

Zaitsev, Vasilii — Udmurt State Univ

For linear time-varying discrete-time systems with incomplete feedback, the notion of uniform consistency is introduced and studied. Necessary and sufficient conditions for uniform consistency are obtained. This property is used for obtaining sufficient conditions of local assignability of Lyapunov spectrum for time-varying discrete-time systems with linear static output feedback.

MoR2V — Hotel VIP-Hall

Applications in Economics, Management and Environmental Science II (Regular Session)

Chair: Zvereva, Olga M. — Ural Federal Univ
Co-Chair: Turygina, Victoria — Ural Federal Univ

16:40-17:00 MoR2V.1

Optimization of Manufacturers Behaviour on the Basis of a Local Economic Agent-Based Model Implementation, pp. 115-120

Zvereva, Olga M. — Ural Federal Univ
Berg, Dmitry — Urals Federal Univ. and Inst. of Industrial Ec. UB RAS
Shevchuk, Georgy K. — Ural Federal Univ
Spasov, Kamen — Sofia Univ. “St.Kliment Ohridski”

In the era of globalization, local economic structures have not lost their significance and must be in the focus of a scientific research. Optimization problem solution could become a solid theoretical foundation for a local economic system effective functioning. To express an objective function in the analytical form in order to implement precise mathematical methods is impossible for a complex system, an economic system has proved to be such type system. Methods based on simulation are believed to be effective for finding solutions of a wide range of optimization problems. This paper details findings of the research aimed at solving optimization problem in terms of revealing optimal agent behavior in the course of exchanges in a local economic system on the basis of agent-based modeling usage. Pursuing this goal, a set of agent-based program models was engineered in Netlogo modelling framework to simulate communication process in a local economic system, and one model from the set, the Strategy Model, is oriented towards optimization problem solution. This problem was solved in terms of the minimum time for completion of exchanges in the whole system, the minimum time necessary for a single agent to complete his exchange operations in order to meet its demands, and the minimum time required for commencement of the manufacturing process. Moreover, as in many researches based on agent-based simulation, a specific and unpredicted phenomenon was revealed, the “selfish” phenomenon.

17:00-17:20 MoR2V.2

The Features of the Presentation of the Topic “Synergetics of the Economics” for Students of Information Technologies, pp. 121-124

Sachkov, Igor — Ural Federal Univ
Dolganov, Aleksey — Ural Federal Univ
Ford, Vitaly — Arcadia Univ
Turygina, Victoria — Ural Federal Univ

The problems of teaching students the synergistic basis of economy is considered. The scheme of presenting the subject is provided, which is adapted to the aspects of modern students teaching.

17:20-17:40 MoR2V.3

Decision-Making in Waste Management: Scenarios Evaluation, pp. 125-129

Turygina, Victoria — Ural Federal Univ
Taubayev, Ayapbergen — Karaganda Ec. Univ. of Kazpotrebsoyuz
Berg, Dmitry — Urals Federal Univ. and Inst. of Industrial Ec. UB
Antonov, Konstantin — Inst. of Industrial Ec. of the Russian Acad. of Scienc
Manzhurov, Igor — Inst. of Industrial Ec. of the Russian Acad. of Scienc

This paper suggests a methodological approach to the problem of waste management. Scenarios evaluation of waste disposal landfills is proposed. Integral index of ecological

hazard based on the number of initial landfill indicators is used for decision-making. So one can calculate the value of integral index due to different waste disposal scenarios and choose the most optimal one. Our approach is illustrated by calculation of scenarios for three landfills of one city in the Russia Arctic Zone for 4 years.

17:40-18:00 MoR2V.4

The Emergence of Feedforward Periodicity for the Fed-Batch Penicillin Fermentation Process, pp. 130-135

Zhai, Chi Beijing Univ. of Chemical Tech
Qiu, Tong Tsinghua Univ
Palazoglu, Ahmet Univ. of California at Davis
Sun, Wei Beijing Univ. of Chemical Tech

In this paper, focus is on identifying the feedforward structure for the emergence of input periodicity at the optimal situation, and the fed-batch penicillin fermentation process is applied for case study. Through information of optimal control, the reversed system analysis methods are constructed, and the criterion for the emergency of optimal periodic control (OPC) is built, and possibly, analytical method to compute out the OPC problem would be proposed.

TuP2IMM	Krasovskii Institute Hall
Plenary Session 2 (Plenary Session)	
Chair: Tarasyev, Alexander M.	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS, Ural Federal Univ
Co-Chair: Palokangas, Tapio	Univ. of Helsinki

09:30-10:30 TuP2IMM.1

Infinite-Horizon Optimal Control. Some Recent Advances and Applications in Economic Growth Theory

Aseev, Sergey — Steklov Mathematical Inst

Infinite-horizon optimal control problems naturally arise in studying different models of optimal dynamic allocation of economic resources, in particular, in growth theory. Typically, the initial state is fixed and the terminal state (at infinity) is free in such problems, while the utility functional to be maximized is given by an improper integral on the time interval $[0,\infty)$. Although the state at infinity is not constrained the maximum principle for such problems may not hold in the normal form, and the standard transversality conditions at infinity may fail. Additional difficulties arise when the model involves a natural resource (renewable or not renewable) as an essential factor of production. In this case, typically, admissible controls are only bounded in an integral sense, which precludes the direct application of the standard existence results. The talk is devoted to some recent results in this field of optimal control and their applications in growth theory.

TuR1A	Hotel Hall A
Real-Time Control Problems I (Regular Session)	
Chair: Matveeva, Natalia	Lomonosov Moscow State Univ
Co-Chair: Demenkov, Maxim	Inst. of Control Sciences

11:00-11:20 TuR1A.1

Hamiltonian Systems in Dynamic Reconstruction Problems, pp. 136-140

Subbotina, Nina — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

We consider dynamic reconstruction (DR) problems for controlled dynamical systems linear in controls and nonlinear in state variables as inaccurate current information about real motions is known. A solution of this on-line inverse problem is obtained with the help of auxiliary problems of calculus of variations (CV) for integral discrepancy functionals. Key elements of the constructions are solutions of hamiltonian systems obtained with the help of optimality conditions for the CV problems.

An illustrating example is exposed.

11:20-11:40 TuR1A.2

A Fast Nonlinear Model Predictive Control Method Based on Discrete Mechanics, pp. 141-146

Ismail, Jawad — Univ. of Kaiserslautern
Liu, Steven — Univ. of Kaiserslautern

Nonlinear Model Predictive Control (NMPC) is an advanced control technique that often relies on a computationally demanding optimization problem and numerical integration algorithms. This paper proposes and investigates a novel method with less computational effort to improve the efficiency of NMPC using a formulation based on discrete mechanics (DM). In contrast to classical NMPC formulations, the proposed method merges the two stages, for solving both the initial value problem (IVP) for prediction as well as the nonlinear programming problem (NLP) for optimization, into a single stage for solving an optimal boundary value problem (BVP) using NLP techniques. By exploiting the structural features of DM a symbolic solution set of the equations of motion are derived offline on each discretization node along the whole optimization horizon. Within an NLP, the optimal solution is efficiently obtained online under the consideration of the boundary constraints. As a benchmark, the widely used NMPC formulation based on direct multiple shooting (MS) method is served to assess the convergence and the excellent real-time performance of this method. The closed-loop performance is demonstrated by the swing-up of an unstable numerical experiment.

11:40-12:00 TuR1A.3

Control Design for Nonlinear Systems Via Controller with Quasi-Fixed Parameters, pp. 147-152

Afanas'ev, Valery — National Res. Univ. Higher School of Ec., Moscow Institute of Electronics and Mathematics
Matveeva, Natalia — Lomonosov Moscow State Univ

The paper presents an approach to design a control of nonlinear dynamical systems based on the extended linearization technique of a mathematical model of an object such that a given quadratic cost function is minimized. In this case, the coefficients of the nonlinear controller are determined by solving Riccati matrix equation with state dependent parameters. A realizability problem of the controller of this sort is computational complexity of the real-time solution. The proposed approach solves the problem by controller coefficients searching at each control time subinterval of the whole control time interval. The presented methodology is illustrated by designing chemotherapy administration for the cancer treatment. The mathematical model of the cancer growth includes interaction between tumor cells, healthy normal cells and activated immune cells. Numerical results show effectiveness of the solutions obtained.

12:00-12:20 TuR1A.4

Constructing Control Lyapunov Functions from Polyhedral Controllable Sets Using Frank–Wolfe Algorithm, pp. 153-156

Demenkov, Maxim — Inst. of Control Sciences

In this work-in-progress paper we propose a method of stabilizing controller synthesis for unstable linear systems with constrained control using polyhedral Lyapunov functions. Our method is based on the Frank–Wolfe algorithm for quadratic optimization, which is suitable for implementation in embedded microprocessors. The method implicitly constructs an inner approximation of polyhedral controllable set for unstable subsystem of lower dimension and then converts its boundary into polyhedral Lyapunov function without explicit construction of the associated polytope.

TuR1B	Hotel Hall B
Robust Control and Stabilization III (Regular Session)	
Chair: Grigorenko, Nikolay	Lomonosov Moscow State Univ
Co-Chair: Yurchenkov, Alexander	V. A. Trapeznikov Inst. of Control Sciences of the Russian Acad. of Sciences

11:00-11:20 TuR1B.1

Position Control of the First Player in a Differential Game, pp. 157-159

Grigorenko, Nikolay — Lomonosov Moscow State Univ

Differential game of two players with dynamics of the motion of the first player described by the second order equation and the second player controls the movement of the target point is considered. The coordinates of the target point become known at the current time. Conditions are proposed for the parameters of the game under which there is a control first player guaranteeing the end of the game in a finite time. The

results of numerical calculations of controls and trajectories for the model parameters of the problem are presented.

11:20-11:40 TuR1B.2

On the Control Design for Linear Time-Invariant Systems with Moments Constraints of Disturbances in Anisotropy-Based Theory, pp. 160-165

Yurchenkov, Alexander — V. A. Trapeznikov Inst. of Control Sciences of RAS

In this paper, the design procedure of anisotropic suboptimal dynamic output regulator for linear discrete time-invariant (LDTI) system is considered. The mean anisotropy level of exogenous disturbance is bounded by the certain positive value. Additional constraints of exogenous disturbance are connected with the first and the second moments. The anisotropic suboptimal regulator design problem is formulated in terms of solvability of linear matrix inequalities (LMI) under convex constraints.

11:40-12:00 TuR1B.3

Construction of Terminal Control for One Nonlinear System, pp. 166-168

Lukianova, Lilia — Lomonosov Moscow State Univ

A mathematical model of motion of a nonlinear controlled system describing the dynamics of a four-screw helicopter with a rotary device for engines is considered. The equations of motion of the model differ from similar models by the form of the equations describing the dynamics of the model. The problem of terminal control in presence of phase constraints is considered. To solve it, the method of dynamic linearization of the location of the control function is applied. The values of the parameters under which the solution of the problem does not contain singularities are found and satisfies the imposed condition of the problem with constraints on the phase variables. For parameters satisfying these conditions numerically the terminal controls and corresponding trajectories are constructed.

12:00-12:20 TuR1B.4

The Anisotropic Norm of Signals: Towards Possible Definitions, pp. 169-174

Chernyshov, Kirill — V.A. Trapeznikov Inst. of Control Sciences

Alternative approaches to define the anisotropic norm of signals are proposed. The paper is motivated by a definition available in the literature, which is based on Kullback—Leibler divergence and, thus, being non-symmetric, what, at least from a theoretical point of view, stimulates to consider some other possibilities in this field.

TuR1V Hotel VIP-Hall

Numerical Methods for Optimization I (Regular Session)

Chair: Kostousov, Victor — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

Co-Chair: Zavadskiy, Sergey — Saint Petersburg State Univ

11:00-11:20 TuR1V.1

Pareto-Optimal Choice of Controller Dimension for Plasma Stabilization System, pp. 175-178

Zavadskiy, Sergey — Saint Petersburg State Univ
Ovsyannikov, Dmitri — Saint Petersburg State Univ

The approach to synthesis and implementation of the controller of ITER plasma stabilization system is considered. The advantage of the presented approach is that the controllers of various dimensions are optimized. Software computes the controllers whose dimension and integral quality criterion are Pareto-optimal. It is described the algorithm to choose the proper controller to final implementation when equations of the plasma stabilization system have a high dimension. The presented integral quality criterion evaluates the upper bound of the ensemble of transient processes for some arbitrary plasma disturbances.

11:20-11:40 TuR1V.2

Optimization Model for Radioactive Waste Transmutation in Advanced Fuel Cycle, pp. 179-183

Golovkina, Anna — Saint Petersburg State Univ
Kudinovich, Igor — Saint Petersburg State Univ
Ovsyannikov, Dmitri — Saint Petersburg State Univ

Optimization approach to effective radioactive waste management in advanced fuel cycle is proposed in the paper. This approach is based on the optimal control theory. The considered controlled system contains a system of ordinary differential equations, describing radioactive isotopes concentration change in time and a number of switching points in which the system state can be changed. The values of variables in the switching points are the optimizing parameters, subjected to determination. Moreover, because the recycling of nuclear waste is supposed to fulfill in subcritical reactor, the constraints on effective multiplication factor are also taken into account during numerical calculations.

11:40-12:00 TuR1V.3

Second-Order Improvement Method for Discrete-Continuous Systems with Intermediate Criteria, pp. 184-188

Rasina, Irina — The Program Systems Inst. of RAS
Danilenko, Olga — Trapeznikov Inst. of Control Sciences of RAS

We consider two-level systems of heterogeneous structure, in particular, discrete-continuous systems (DCS) for the case in which all homogeneous lower-level subsystems are not only connected by a common functional, but also have their own goal objectives. Based on modification of the previously obtained Krotov's sufficient optimality conditions, we develop an improvement method that contains various proximity regulators of neighboring approximations at different levels. An illustrative example is provided.

12:00-12:20 TuR1V.4

Mapping Problems of Geophysical Fields in Ocean and Extremum Problems of Underwater Objects Navigation, pp. 189-194

Kostousov, Victor — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Berdyshev, Vitalii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Kiselev, Lev — Inst. of Marine Tech. Problems, Far East Branch of RAS

The paper focuses on mathematical and technical problems of navigation and control of unmanned underwater vehicles (AUV). Such problems arise during geophysical fields mapping, development of map-aided navigation methods, and optimal routes finding. To address map creation problem, the results of measurements on trajectory were used; then the field map reconstruction in fixed frame of a reference followed. The paper discusses optimization of the survey routes and optimization of measurements of the parameters of local fields and their anomalies on trajectory of an AUV. The field map reconstruction methods based on measurement results on trajectory are considered. Some mathematical problems of navigation by geophysical field maps are discussed. More specifically, matching algorithms for fragment taken in motion with a reference map are studied, the problem of the best reference map approximation for data compression on the AUV board is considered, the field informativity criterion is offered, and the problem of optimal route construction on the basis of such criterion is solved. The estimates obtained in the paper are based on theoretical studies, the results of simulation experiments, and field experimental trials of the AUV systems.

TuR2A	Hotel Hall A
Optimal Control III (Regular Session)	

Chair: Gusev, Mikhail — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Co-Chair: Patsko, Valerii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

14:40-15:00 TuR2A.2

Some Aspects of Statistically Uncertain Minimax Estimation, pp. 195-200

Ananyev, Boris — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

In this work, minimax methods of estimation for discrete time stochastic systems are considered. In the beginning we deal with one-stage systems in order to describe in details two methods of point estimation. After that these methods are transferred on multi-stage systems. Some special cases and examples are also examined.

15:00-15:20 TuR2A.3

Attainability Set at Instant for One-Side Turning Dubins Car, pp. 201-206

Patsko, Valerii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Fedotov, Andrey — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

Three-dimensional attainability set “at instant” for a non-linear controlled system is studied, which is often called the “Dubins car”. A controlled object moves in the plane. It has linear velocity of a constant magnitude and bounded turn radius. The case is explored when the object can turn to one side only. Moreover, a rectilinear motion is prohibited by the constraints onto the control. We prove that the sections of the attainability set by planes orthogonal to the angle coordinate are convex. The geometric structure of these sections is analyzed.

15:20-15:40 TuR2A.4

On Convexity of Reachable Sets of a Nonlinear System under Integral Constraints, pp. 207-212

Gusev, Mikhail — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

We consider a nonlinear affine-control system with constraints given by a level set of an integral functional of the control and the state variables. The convexity of reachable sets for the case when this functional is the sum of a convex quadratic functional of the control and a small functional of the state is studied. We also consider an autonomous control system on a small time interval and prove the convexity of reachable sets assuming appropriate asymptotics for controllability Gramian. A procedure for calculating the reachable sets is described and results of numerical simulations are presented.

15:20-15:40 TuR2A.5

A Maximum Principle for One Infinite Horizon Impulsive Control Problem, pp. 213-218

Khlopin, Dmitry — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The paper is concerned with a nonlinear impulsive control system with trajectories of bounded variation. Necessary conditions of optimality in a form of the Maximum Principle are derived for a class of infinite horizon impulsive optimal control problems. For the overtaking optimality criterion under the assumption that all gradients of the payoff function are bounded, we construct a transversality condition for the adjoint variable in terms of limit points of the gradient of the payoff function. In the case when this limit point is unique, this condition supplements the system of the Maximum Principle and determines a unique solution of the adjoint system. This solution can be written explicitly with the use of the (Cauchy type) formula proposed earlier by S.M. Aseev and A.V. Kryazhimskii. The key idea of the proof is the application of the convergence of subdifferentials within Halkin's scheme.

TuR2B	Hotel Hall B
Differential Games I (Regular Session)	

Chair: Kleimenov, Anatolii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Co-Chair: Gomoyunov, Mikhail — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

14:20-14:40 TuR2B.1

Altruistic and Aggressive Types of Behavior in a Non-Antagonistic Positional Differential Two-Person Game, pp. 219-224

Kleimenov, Anatolii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

A non-antagonistic positional differential two-person game is considered in which each of the two players, in addition to the usual normal (nor) type of behavior oriented toward maximizing own functional, can use other types of behavior. In particular, it is altruistic (alt), aggressive (agg) and paradoxical (par) types. It is assumed that in the course of the game players can switch their behavior from one type to another. In this game, each player along with the choice of positional strategy also chooses the indicator function dened over the whole time interval of the game and taking values in the set {nor; alt; agg; par}. Player's indicator function shows the dynamics for changing the type of behavior that this player adheres to. The concept of BT-solution for such game is introduced. Using players types of behavior other than normal, can lead to outcomes more preferable to them than in a game with only a normal type of behavior. An example of a game with the dynamics of simple motion in the plane and phase constraints illustrates the procedure for constructing BT-solutions.

14:40-15:00 TuR2B.2

Application of I-Smooth Analysis to Differential Games with Delays, pp. 225-227

Andryushechkina, Nadia — Ural State Agrarian Univ
Ivanov, Aleksey V. — Ural Federal Univ
Kim, Arkadii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

In this paper we present application of i-smooth analysis to approach-evasion linear differential game with delay. The main goal is to show that according to the methodology of i-smooth analysis one can realize extremal shift procedure by the finite dimensional component of the system state.

15:00-15:20 TuR2B.3

On the Stability of a Solution of a Guarantee Optimization Problem under a Functional Constraint on the Disturbance, pp. 228-233

Gomoyunov, Mikhail — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Karandina, Valeriya — Ural Federal Univ
Mezentsev, Ilya — Ural Federal Univ. Named after B.N. Eltsin
Serkov, Dmitrii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The paper deals with a control problem for a dynamical system under disturbances. In addition to geometric constraints on the disturbance, it is supposed that all disturbance realizations belong to some unknown L1-compact set. The control is aimed at minimization of a given quality index. Within the game-theoretical approach, the problem of optimizing the guaranteed result is studied. For solving this problem, we use a control procedure with a guide. The paper is focused on the questions of stability of this control procedure with respect to informational and computational errors. The results are illustrated by numerical simulation.

15:20-15:40	TuR2B.4

An Approach Problem with an Unknown Parameter and Inaccurately Measured Motion of the System, pp. 234-238

Ershov, Aleksandr — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Ushakov, Andrey — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Ushakov, Vladimir — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

A control system with an unknown constant parameter is considered on a finite time interval. The actual value of the parameter in this control system is unknown to the person controlling the system at the moment when the systems starts moving. Finding an unknown parameter is made by applying a trial control to the control system for a short period of time along with monitoring the corresponding change in the movement of the system. After finding the approximate determination of the unknown parameter we can construct resolving control in the usual way, but we must take into account the additional error associated with the process of approximate determination of the parameter. In this paper, we investigate the influence of the error of measuring phase variable on the accuracy of unknown parameter recovery.

TuR3A Hotel Hall A

Optimal Control IV (Regular Session)

Chair: Kostousova, Elena K. — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Co-Chair: Kandoba, Igor — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

16:10-16:30	TuR3A.1

Maximal Linked Systems and Ultrafilters in Abstract Attainability Problem, pp. 239-244

Chentsov, Alexander — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The given investigation is oriented to study of generalized elements (GE) for solving problems of attainability under constraints of asymptotic character. But, the development of this direction required a special study of the issues connected with structure of the GE themselves. In considered problems, GE are used for extension of the space of usual solutions or usual controls. This extension has an analogy with extension of topological spaces (TS). So, we use compactification procedures. It is important to know the possibilities for realization of the corresponding compactification of the initial solution space. This investigation is directed at this work. We consider topological constructions realized by ultrafilters of widely understood measurable spaces.

16:30-16:50	TuR3A.2

State Estimates of Bilinear Discrete-Time Systems with Integral Constraints through Polyhedral Techniques, pp. 245-250

Kostousova, Elena K. — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

We consider bilinear discrete-time systems for the case when interval bounds on the coefficients of the system are imposed, additive input terms are restricted by integral constraints, and initial states are restricted by given sets. Several ways for constructing external parallelepiped-valued estimates of reachable sets of such systems are proposed. One of the above techniques is based on obtaining recurrence relations for reachable sets in the “extended” phase space and constructing corresponding estimates in the form of polytopes of some special shape.

17:10-17:30	TuR3A.4

Admissible Controls in a Nonlinear Time-Optimal Problem with Phase Constraints, pp. 251-255

Kandoba, Igor — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Koz'min, Ivan — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Novikov, Dmitry — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The paper is devoted to constructing admissible controls in a problem of optimal control by a nonlinear dynamic system under constraints on the current phase state. The dynamic system under consideration describes the controlled motion of a carrier rocket from the launching point to the time when the carrier rocket enters a given elliptic earth orbit. A problem consists in designing a program control for the carrier rocket that provides the maximal value of the payload mass led to the given orbit and the fulfillment of a number of additional restrictions on the current phase state of the dynamic system at the atmospheric part of the trajectory. The restrictions considered are due to the need to take into account the values of the dynamic velocity pressure, the attack angle and slip angle when the carrier moves in dense layers of the atmosphere. Such a problem is equivalent to a nonlinear time-optimal problem with phase constraints for carrier rockets of some classes. The algorithm for constructing admissible controls ensuring the fulfillment of additional phase constraints is suggested. The methodological basis of this algorithm is the application of some predictive control. This control is constructed in the problem without taking into account the constraints above. For a deterministic model of the atmosphere, such a predictive control is used to predict the values of a part of the phase state of the dynamic system at the next time. The prediction results are applied in the procedure of desired control construction. This procedure essentially takes into account specific features of the additional constraints. The results of numerical modeling are presented.

17:30-17:50	TuR3A.5

Approximation of Linear Conflict-Controlled Neutral-Type Systems, pp. 256-261

Plaksin, Anton — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

We consider a dynamical system described by linear neutral-type functional-differential equations which is controlled under conditions of unknown disturbances. This system is approximated by a system of ordinary differential equations. An aiming procedure between the initial and approximating systems is elaborated. Using such procedure, results of the control theory for ordinary differential systems can be applied to control of the initial system.

TuR3B Hotel Hall B

Differential Games II (Regular Session)

Chair: Serkov, Dmitrii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Co-Chair: Tarasyev, Alexander M. — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

16:10-16:30	TuR3B.1

Traversing Target Points under Lack of Information: A Game-Theoretical Approach, pp. 262-266

Lukoyanov, Nikolay — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Gomoyunov, Mikhail — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

A dynamical object controlled under conditions of unknown disturbances or counter-actions is considered. The goal is to bring the object to given target points at given times regardless of the disturbance actions. To solve this problem,

the quality index is introduced that evaluates the distance between the object and target points at the indicated times, and a zero-sum differential game is considered in which the control actions minimize this quality index while the disturbance actions maximize it. The initial problem is reduced to calculating the game value and constructing a saddle point of the game. The corresponding resolving procedure is proposed that is based on the upper convex hulls method. An example is considered. Results of numerical simulations are presented.

16:10-16:30 TuR3B.1

On a Condition of Existence of Non-Anticipating Selections, pp. 267-270

Serkov, Dmitrii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The hereditary selections of multi-functions play an important role in the theory of differential games in connection with the construction of resolving quasi-strategies. The existence of a non-anticipating selection of a non-anticipating multi-function is considered. In most cases important for applications, it is known that any non-anticipating multi-function with non-empty compact values has a non-anticipating selection. Namely, the result is valid when the non-anticipation property is defined by a totally ordered family in the domain of “time” variable. In this note, we show that the condition is essential: when the family is not totally ordered, there exists a hereditary multi-function with non-empty compact values that has no non-anticipating selections.

16:30-16:50 TuR3B.2

Demand Functions in Dynamic Games, pp. 271-276

Krasovskii, Nikolay — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

Tarasyev, Alexander M. — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The paper is devoted to construction of solutions in dynamic bimatrix games. In the model, the payoffs are presented by discounted integrals on the infinite time horizon. The dynamics of the game is subject to the system of the A.N. Kolmogorov type differential equations. The problem of construction of equilibrium trajectories is analyzed in the framework of the minimax approach proposed by N.N. Krasovskii and A.I. Subbotin in the differential games theory. The concept of dynamic Nash equilibrium developed by A.F. Kleimenov is applied to design the structure of the game solution. For obtaining constructive control strategies of players, the maximum principle of L.S. Pontryagin is used in conjunction with the generalized method of characteristics for Hamilton—Jacobi equations. The impact of the discount index is indicated for equilibrium strategies of the game and demand functions in the dynamic bimatrix game are constructed.

16:50-17:10 TuR3B.3

On Limit and Infimum-Captures in Pursuit-Evasion Problems, pp. 277-280

Yufereva, Olga — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

In this paper, we show an example of two-person pursuit-evasion game with infinite horizon where two kinds of capture turn out to differ. One of them, the infimum capture, is a standard kind of capture, while the limit capture, introduced in this paper, is its stronger variant. Both variants of capture have applications, but it is not known in advance whether they always exist simultaneously. The considered example is based on Lion and Man game, i.e. on the game with equal players' capabilities. The considered space is a compact geodesic space.

WeP3IMM	Krasovskii Institute Hall
Plenary Session 3 (Plenary Session)	
Chair: Chernousko, Felix L.	Ishlinsky Inst. for Problems in Mechanics, RAS
Co-Chair: Gusev, Mikhail	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

09:30-10:30 WeP3IMM.1

The Theory of Group Control: A Road Map

Kurzhanski, Alexander B. — Lomonosov Moscow State University

The presentation deals with description of feedback control strategies for a group of systems involved in jointly solving the problem of reaching a given target set under stationary or moving obstacles while ensuring collision avoidance among the members of the group. The feedback nature of the overall solutions also requires to solve an array of subproblems of on-line group observations. Finally described is the total procedure of optimalizing such controlled processes.

WeR1A	Hotel Hall A
Optimal Control V (Regular Session)	
Chair: Aksikas, Ilyasse	Qatar Univ
Co-Chair: Altmann, Bettina	Leibniz Univ. Hannover

11:00-11:20 WeR1A.1

An Existence Result for Infinite-Horizon Optimal Control Problem with Unbounded Set of Control Constraints, pp. 281-285

Aseev, Sergey — Steklov Mathematical Inst

We consider a class of infinite-horizon optimal control problems with not necessarily bounded set of control constraints. Using finite-horizon approximations and tools of the Pontryagin maximum principle sufficient conditions for existence and boundedness of an optimal control are developed in the general nonlinear case. Application of the result obtained to a model of optimal exploitation of a renewable resource is presented.

11:20-11:40 WeR1A.2

Optimal Boundary Control for Selective Catalytic Reduction Distributed Parameter Model, pp. 286-291

Aksikas, Ahmed — Univ. of Alberta
Aksikas, Ilyasse — Qatar Univ
Hayes, Robert — Univ. of Alberta
Forbes, J. Fraser — Univ. of Alberta

This paper is devoted to design a model-based boundary optimal controller for selective catalytic reduction system. The mathematical model consists of coupled parabolic hyperbolic PDEs with an ODE. The main objective is to manipulate the ammonia gas at the inlet of the SCR in order to reduce the amount of NOx and ammonia slip as much as possible. The augmented in nite-dimensional state space representation has been used in order to solve the corresponding linear-quadratic control problem. The dynamical properties of both the linearized system and its augmented version have been studied. Under some technical conditions, it has been shown that the augmented system generates an exponentially stabilizable and detectable C0-semigroups. The linear-quadratic control problem has been solved for the augmented system. A decoupling technique has been implemented to decouple and solve the corresponding Riccati equation. An algorithm has been developed to describe the steps of solving the Riccati equation. Numerical simulations for the closed-loop system have been implemented to show the controller performances.

11:40-12:00 WeR1A.3

Image-Based Discrete-Time Optimal Feedback Control for an Optomechanical Derotator, pp. 292-297

Altmann, Bettina — Leibniz Univ. Hannover
Pape, Christian — Leibniz Univ. Hannover
Reithmeier, Eduard — Leibniz Univ. Hannover

An optomechanical derotator is an optical system that can be used to extend various measurement methods so they can be applied to rotating measurement objects. The function principle is to manipulate the image of the rotating measurement object by means of rotating reflective components inside the derotator. Thus it appears stationary in the measurement data. For this it is inevitably that the angular position and velocity of the derotator are controlled in such way that they always amount to half that of the measurement object. It is therefore necessary to adjust the derotator with the help of an implemented controller. Since we want to acquire the reference input of the control with a high-speed camera and image processing algorithms the sampling time of the control must be adapted to the rather long computation time of the image processing. As a result, the use of analog control techniques is prohibited so that a digital controller has to be implemented. This paper proposes an approach where an image-based discrete-time linear-quadratic regulator is used to satisfy the requirements concerning the angular position and velocity of the derotator. To improve its performance, it is supplemented by integral action and a model-based feedforward control. Furthermore, the image processing algorithms by which the reference input of the control is determined are described. Finally, it is demonstrated that this controller concept produces the desired result by generating a standing image of a rotating object with a camera and the derotator.

12:00-12:20 WeR1A.4

Synthesis of Adaptive Control of Robotic Manipulator by the Method of Lyapunov Functions, pp. 298-303

Bragina, Asia — South Ural State Univ. (National Res. Univ)
Shcherbakov, Vasily — South Ural State Univ. (National Res. Univ)
Shiryaev, Vladimir — South Ural State Univ. (national Res. Univ)

The control algorithm of the movement of robotic manipulator (RM) to the point of the program trajectory by the method of Lyapunov function is obtained. The stability of a dynamical system in the entire phase space and its dissipativity in the region of the phase space are investigated with a significant influence of the disturbing moments in operating conditions. The influence of measurement errors of the state vector of RM on the formation of control is taken into account. The proposed adaptive controller can be applied both at the design stage and in real time.

WeR1B	Hotel Hall B
Control Design for Hybrid Systems (Regular Session)	
Chair: Pereira, Fernando Lobo	Porto Univ
Co-Chair: Staritsyn, Maxim	Matrosov Inst. for System Dynamics and Control Theory, Siberian Branch of the Russian Acad. of Sciences

11:00-11:20 WeR1B.1

Dynamic Programming and Control Synthesis for Variational Problems with Polynomial Impulses, pp. 304-309

Goncharova, Elena — Inst. for System Dynamics and Control Theory SB RAS
Staritsyn, Maxim — Matrosov Inst. for System Dynamics and Control Theory, SB RAS

The paper suggests a framework of control synthesis (feedback) for differential systems driven by nonlinear

impulses. We propose a simple but relevant notion of control synthesis and a related concept of sampling solution. For extremal problems stated for input-polynomial systems, we fix two connected issues: establish the dynamic programming principle, including the characterization of the value function and verification theorem (sufficient optimality condition), and design an optimal synthesis procedure. Finally, we discuss a different, to some extent “dual” to the verification theorem, issue – a sufficient condition for non-optimality, – which performs an application of the control synthesis to discarding non-optimal extrema of the impulsive maximum principle.

11:20-11:40	WeR1B.2

On the Ell-Attainability Sets of Continuous Discrete Functional Differential Systems, pp. 310-313

Maksimov, Vladimir — Perm State Univ

For a functional differential system with continuous and discrete times, the problem of control with respect to an on-target vector-functional ell is considered. For the case of polyhedral constraints concerning control, the notion of the ell-attainability is introduced and relationships to describe this set are derived.

11:40-12:00	WeR1B.3

A General Attainable-Set Model Predictive Control Scheme. Application to AUV Operations, pp. 314-319

Gomes, Rui — Porto Univ
Pereira, Fernando Lobo — Porto Univ

In this article, a Model Predictive Control (MPC) scheme that, by taking advantage of the control problem time invariant ingredients, replaces as much as possible the on-line computational burden of the conventional schemes, by off-line computation, is presented and its asymptotic stability shown. The generated data is stored onboard in look-up tables and recruited and adapted on-line with small computation effort according to the real-time context specified by communicated or sensed data. This scheme is particularly important to the increasing range of applications exhibiting severe real-time constraints. The approach presented here provides a better re-conciliation of onboard resources optimization with state feedback control — to deal with the typical a priori high uncertainty — while managing the formation with a low computational budget which otherwise might have a significant impact in power consumption.

12:00-12:20	WeR1B.4

Supervisory Model-Based Control Using Mixed Integer Optimization for Stationary Hybrid Fuel Cell Systems, pp. 320-325

Neisen, Verena — RWTH Aachen Univ
Baader, Florian Joseph — Inst. of Automatic Control RWTH Aachen
Abel, Dirk — RWTH-Aachen Univ

This paper presents an application-oriented comparison of optimization approaches for Model-based Control of a stationary hybrid energy system. The energy system consists of a hybrid storage system with a battery and a hydrogen storage including an electrolyzer and a fuel cell system. The hybrid storage aims at improving the supply security of the intermittent renewable energy sources wind and photovoltaic in a grid-connected context. We show the potential of Mixed Integer Linear Programming (MILP) with a linear cost function in the optimization of a supervisory Model-based Control. The optimization takes into account minimum power for electrolyzer and fuel cell. Furthermore, the non-linear partial load behavior of the components is extracted from experimental data and in good fit modeled via piecewise affine functions. By utilizing this MILP in the optimization we increase the hybrid discharging effciency by 7% compared to Linear Programming.

WeR1V	Hotel VIP-Hall
Numerical Methods for Optimization II (Regular Session)	
Chair: Sheludko, Anton	South Ural State Univ
Co-Chair: Glazunova, Anna	Melentiev Energy Systems Inst. SB RAS

11:00-11:20	WeR1V.1

Numerical Stackelberg Solutions in a Class of Positional Differential Games, pp. 326-330

Kuvshinov, Dmitry — Yeltsin Ural Federal Univ
Osipov, Sergei — Yeltsin Ural Federal Univ

We consider a problem of numerical construction of a Stackelberg solution in a differential game with closed-loop information structure and terminal player payoffs. It is divided into two subproblems: the problem of computing of so-called “admissible” motions and the optimization problem on the set of admissible motions. We focus on the latter problem and consider two approaches: enumeration of the follower player payoffs and enumeration of the leader player payoffs. Algorithms implementing both approaches are presented and tested on a model system.

11:20-11:40	WeR1V.2

Estimation of Total Transfer Capability in Intersystem Tie Lines of Electric Power Systems, pp. 331-336

Glazunova, Anna — Melentiev Energy Systems Inst. SB RAS
Aksaeva, Elena — Melentiev Energy Systems Inst. SB RAS

The paper presents a method for real-time calculation of total transfer capability on the basis of a trade-off approach, witch gives optimal values of total transfer capability in all considered lines. To implement the trade-off approach we introduce a two-level structure to control the interconnected electric power systems, establish Control center receiving data from all power systems taking part in generation of a trade-off decision, perform state estimation and estimation of total transfer capability, and then work out a single rule for additional loading of controlled cutsets. An example of the calculation of total transfer capability in two cutsets under their simultaneous loading is presented.

11:40-12:00	WeR1V.3

Parameter Estimation for One-Dimensional Chaotic Systems by Guaranteed Algorithm and Particle Swarm Optimization, pp. 337-342

Sheludko, Anton — South Ural State Univ

The problem of parameter estimation is considered for chaotic systems described by one-dimensional discrete maps. The article presents a two-stage estimation technique that combines the ideas of guaranteed (set-membership) approach and swarm intelligence. The first stage is the preprocessing of measurements by the guaranteed algorithm. The result of the guaranteed estimation is interval estimates of the unknown variables (the initial condition and parameter of the chaotic map). The second stage is the minimization of the cost function using particle swarm optimization. The previously computed interval estimates define the set of possible values of the cost function arguments. It decreases the number of local minima of the cost function and improves the convergence of the optimization algorithm. The proposed estimation technique is useful in the case of a small number of available measurements.

12:00-12:20	WeR1V.4

A New Approximate Method for Construction of the Normal Control, pp. 343-348

Krupennikov, Evgeniy Aleksandrovitch — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The problem of construction of the normal control (namely, the control with the least norm in L^2 space) that generates a given trajectory of a control system is considered.

A new method for constructing approximations of the normal control is suggested for a class of control systems with dynamics linear in controls and non-linear in state coordinates where the dimension of the control parameter is greater than or equal to the dimension of the state variables. This method relies on necessary optimality conditions in auxiliary variational problems.

An illustrating example is exposed. The results of numerical simulation are compared with the results obtained with another approach.

WeR2A	Hotel Hall A
Real-Time Control Problems II (Regular Session)	
Chair: Olaru, Sorin	CentraleSupélec, Université Paris-Saclay
Co-Chair: Samsonyuk, Olga	Matrosov Inst. for Systems Dynamics and Control Theory of Siberian Branch of the Russian Acad. of Sciences

14:20-14:40	WeR2A.1

Model Predictive Speed Control of a Wind Turbine System Test Bench, pp. 349-354

Leisten, Christian — RWTH Aachen Univ
Jassmann, Uwe — RWTH Aachen Univ
Balshüsemann, Johannes — RWTH Aachen Univ
Abel, Dirk — RWTH-Aachen Univ

This paper presents a Model Predictive Speed Control of a Wind Turbine System Test Bench. A System Test Bench enables the investigation of the total Wind Turbine drive train dynamic by replacing the rotor and the grid with a controllable load application system. Its basic and safe operation mode is speed control. This must be robust and offer both a dynamic reference tracking and disturbance rejection of the generator torque of the testee while considering the actuator limitation of the motor. Aside, due to the missing rotor, the frequency response of the Wind Turbine on the System Test Bench strongly differs from the original one. The resulting shifted eigenfrequencies must be actively damped for a safe and realistic operation. The Model Predictive Control presented in this paper naturally satisfies all these requirements. The developed control is validated in simulation showing excellent results. Also, it is implemented on a real time system at the System Test Bench and put into first operation at full load of the Wind Turbine. The generator speed is already controlled stably at the rated power PrWT = 2.75 MW oppressing generator torque steps. However it shows an oscillation around the operating point, so further work must be done to reproduce the same control quality in experiment.

14:40-15:00	WeR2A.2

Robust MPC for Temperature Management on Electrical Transmission Lines, pp. 355-360

Straub, Clémentine — CentraleSupélec, Université Paris-Saclay
Olaru, Sorin — CentraleSupélec, Université Paris-Saclay
Maeght, Jean — Réseau de Transport d'Electricité (RTE)
Panciatici, Patrick — Réseau de Transport d'Electricité (RTE)

In the current context of high integration of renewable energies, maximizing infrastructures capabilities for electricity transmission is a general need for Transmission System Operators (TSO). The French TSO, RTE, is developing levers to control power flows in real-time: renewable production curtailment is already employed and large battery storage systems are planned to be installed for congestion management in early 2020. The combination of these levers with the use of Dynamic Line Rating (DLR) helps exploiting the lines at the closest of their limit by managing their temperature in real-time. Unnecessary margins can be reduced, avoiding congestion and excessive generation curtailment. In particular, there is a possible interesting correlation between the transits increase due to high wind farms generation and the cooling effect of wind on power lines in the same area. In order to optimize the electrical transmission network capacities, the present paper advocates the use of a temperature management model, mixing production curtailment and large batteries as control variables. A robust Model Predictive Control framework for local control on electrical lines temperature is presented based on the regulation within tubes of trajectories. Simulations on the French electrical network are conducted to show the effectiveness of the optimization-based control design.

15:00-15:20	WeR2A.3

BV Solutions of Rate Independent Processes Driven by Impulsive Controls, pp. 361-366

Samsonyuk, Olga — Matrosov Inst. for Systems Dynamics and Control Theory, SB of RAS
Timoshin, Sergey A. — Inst. for Systems Dynamics and Control Theory, SB of RAS

An extension to discontinuous inputs of bounded variation of the play operator is presented. The motivation for such an extension comes from optimal impulsive control problems with hysteresis. The latter is introduced by means of variational inequalities modeling the action of the play operator on the BV-inputs. Our extension is applied to the graph completions of BV-functions and it allows us to study impulsive control systems characterized by measure-driven differential equations with nonlinear terms of hysteresis type. Some approximation results for impulsive processes are also provided.

15:20-15:40	WeR2A.4

Satisfying the Cost Constraints in a Network System Operating by the Consensus Protocol with Different Task Priorities, pp. 367-372

Amelina, Natalia — Saint Petersburg State Univ
Granichin, Oleg — Saint Petersburg State Univ
Ivanskiy, Yury — Saint Petersburg State Univ
Jiang, Yuming — Norwegian Univ. of Science and Tech
Granichina, Olga — Saint Petersburg State Univ

A multi-agent network system of different computing nodes processing tasks of different priority levels is considered. Agents balance their loads for each priority level by achieving consensus of their load values. Agents operate by local voting protocol and exchange information about their states in presence of noise in communication channels in the system with switching topology. The network usage for task exchange is limited by the constraints on average cost of utilized links. A way to meet the constraints by randomization of link usage is considered. Simulation illustrating the considered approach is provided.

WeR2B	Hotel Hall B
Optimization Methods I (Regular Session)	
Chair: Samylovskiy, Ivan	Moscow State Univ
Co-Chair: Sotnikova, Margarita	Saint Petersburg State Univ

14:20-14:40	WeR2B.1

Generalized a Bottleneck Routing Problem: Dynamic Programming and the Start Point Optimization, pp. 373-377

Sesekin, Alexander — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Chentsov, Alexander — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Chentsov, Alexei — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

One routing problem with constraints is considered. These

constraints are reduced to precedence conditions which be to visiting sequence of megalopolises. This sequence is selected together with concrete trajectory and initial state for minimization of nonadditive criterion. These criterion is some generalization of known criterion for the bottleneck routing problem. The basis singularity of the used solving method consists of using of unique dynamic programming procedure for all initial states. The used criterion includes a controlled parameter influences on significance of different fragments of solution.

14:40-15:00 WeR2B.2

On One Problem of Reconstructing Matrix Distances between Chains of DNA, pp. 378-383

Melnikov, Boris — Russian State Social Univ
Trenina, Marina — Togliatti State Univ
Kochergin, Alexander — Russian State Social Univ

In practice, there is a need to calculate the distances between sequences of different nature. Similar algorithms are used in bioinformatics to compare sequenced genetic chains. Due to the large dimension of such chains, it is necessary to use heuristic algorithms that give approximate results. There are various heuristic algorithms for determining the distance between genomes, but the obvious disadvantage in calculating the distance between the same pair of DNA strings is to obtain several different results when using different algorithms for calculating metrics. Therefore, there is a problem of assessing the quality of the used metrics (distances), the results of which can be concluded about the applicability of the algorithm to various studies. One of the problems considered in biocybernetics is the problem of recovering the matrix of distances between DNA sequences, when not all elements of the considered matrix are known at the input of the algorithm. In this regard, a problem of developing method for comparative evaluation of algorithms calculating distances between sequences is used for another problem, i.e., the problem of restoring the matrix of distances between DNA sequences. In this paper, we consider the possibility of using the developed and studied by us earlier method of comparative evaluation of algorithms for calculating distances between a pair of DNA strings to restore the partially filled matrix of distances. Matrix recovery occurs as a result of several computational passes. Estimation of unknown matrix elements are averaged in a special way with the use of so-called risk function, and the result of this averaging is considered as the resulting value of the unknown element.

15:00-15:20 WeR2B.3

On One Method to Obtain Stationarity Conditions for an Optimal Control Problem Trajectory with a Smooth Boundary Contact, pp. 384-388

Samylovskiy, Ivan — Moscow State Univ

We consider a class of optimal control problems with a scalar state constraint. Studied problem involves “inertial” of prescribed order dynamics for constrained state variable. For a trajectory with a smooth contact (of order corresponding to “inertial delay” order) with a single boundary subarc, we first obtain, using a special technique (two-stage variation approach), optimality conditions in the form of Gamkrelidze, and then obtain the full set of optimality conditions in the Dubovitskii—Milyutin form, including the nonnegativity of the measure density and its atoms at the junction points.

15:20-15:40 WeR2B.4

Algorithms for Motion Optimization on a Given Trajectory Taking into Account Weather Forecast and Constraints, pp. 389-394

Sotnikova, Margarita — Saint Petersburg State Univ
Veremey, Evgeny — Saint Petersburg State Univ

The paper is devoted to the problem of motion optimization of a ship on a given long trajectory with respect to weather forecast and additional constraints. This problem has practical meaning for long distances, where saving of fuel consumption and reducing travel time is of significant importance. A finite-dimensional formulation of the optimization problem is considered taking into account the mathematical model of ship motion, weather forecast, constraints and given cost functionals. The computational algorithms for calculation of travel time and fuel consumption are proposed. The main result is presented by the algorithm for optimizing the velocity distribution on a given trajectory. This algorithm is based on the representation of the route of motion on a fixed trajectory in two-dimensional space. The obtained results are demonstrated by illustrative examples.

WeR2V Hotel VIP-Hall

Applications in Economics, Management and Environmental Science III (Regular Session)

Chair: Mitsek, Sergey — Liberal Arts Univ
Co-Chair: Petrosian, Ovanes — Saint Petersburg State Univ

14:20-14:40 WeR2V.1

Econometric Model of Russian Federation: Analysis and Forecasts for 2018 - 2019, pp. 395-400

Mitsek, Sergey — Liberal Arts Univ

The objectives of the paper are to analyze the macroeconomic trends in Russian Federation, to identify the factors of growth of its economy and to make forecasts for the next two years. The methodological tool is the econometric model which consists of 32 equations and 80 identities that describe the relationships between 125 variables. They consist of 13 exogenous and 112 endogenous variables. Among the first ones there are the capital account balance, the monetary base, economically active population, government consumption deflator and export and import prices. The main macroeconomic indicators such as the GDP volume, different price indexes, investment in fixed assets, bank loans and deposits, employment and average wages, exchange rate and volumes of export and import were included as the endogenous variables. The parameters of the equations were estimated by ML–ARCH and by OLS methods. The quarterly data for Q1 1999 – Q4 2017 were used as a sample. The main result is that under the assumption of the same economic policy and foreign economic conditions the average annual growth rate of Russian economy for 2018–2019 will be not more than 1–2% annually while the inflation is increasing to 8–9% annually. Active monetary policy increases the economic growth only slightly. Freezing the prices of government purchases has a strong positive impact on the economic growth while reducing the inflation. Such outcome is the result of reduction of total factor productivity of Russian economy and of inadequate investment. The model demonstrates weakening of impact of external economic factors on Russian economy and strengthening of the role of internal ones.

14:40-15:00 WeR2V.2

Optimization of the Graduates Labour Market: Dynamic Modeling, Russian and Foreign Experience, pp. 401-406

Sudakova, Anastasiya — Ural Federal Univ. Named after the First President of Russia
Agarkov, Gavriil — Ural Federal Univ. Named after the First President of Russia
Shorikov, Andrey — Ural Federal Univ. Named after the First President of Russia

The article substantiates the relevance and importance of constructing a model for optimizing the structure of graduate training and output by universities to meet the labour market needs, and presents a review of the literature focused on this issue. In addition, the authors examine the two existing approaches to determining the tools for achieving balance in the labour market: econometric, whereby the main criterion for assessing the quality of equilibrium is the wage level, and dynamic models. The authors present their own approach to constructing an optimization deterministic dynamic model that does not require knowing the probability characteristics of the

process under consideration. The proposed solution is constructed using a deterministic approach in which the following vectors are formed: the phase vector, whose coordinates are the values of the parameters describing the training process in higher education institutions at a certain fixed point in time; the controlling action vector (control vector) that allows influencing (by means of funding, the school-leaving exam score required for admission and other parameters) the structure, volume and quality of university training on various degree courses (educational programs), as well as the corresponding deterministic restrictions. The construction of the optimisation model is realised in two stages. At the first stage, a discrete dynamic model is formed that describes the influence of the control vector on the parameters of the system parameters phase vector. At the second stage, restrictions are formed on the parameters of the mathematical model that take into account the labour market demand for university graduates, and the quality criteria (functionals) that allow evaluating the process under consideration at a set final point in time.

15:00-15:20 WeR2V.3

Dynamic Modeling of Labor Migration Impact on the Economic System Development, pp. 407-412

Tarasyev, Alexandr A. — Ural Federal Univ. Named after the First President of Russia
Jabbar, Jeenat — Refugee and Migratory Movements Res. Unit (RMMRU)

In this paper we present a model description of the impact of labor migration on the development of economic systems in countries of migration attraction. It should be emphasized that labor migration is one of the major factors in the development of the labor market. The inflow of migrants into a region should correspond to the labor resources demand of the labor market. To estimate and predict the migration flows between countries with different level of socio-economic development we elaborated a dynamic multi-factor model, which is based on the assumptions of the positional games theory and allows to predict the behavior of each individual, depending on economic factors. According to the model idea, potential migrants have the information on the difference of living and working conditions in both countries of origin and migration attraction. This model takes into account several economic theories of migration and describes the migrant's behavior in terms of migration barriers absence. At the final step of modeling we provide an assessment of migration impact on the development of socio-economic systems in the countries of migration attraction using an approach, which is based on a production function of Cobb—Douglas type.

15:20-15:40 WeR2V.4

Cooperative Differential Games with Dynamic Updating, pp. 413-417

Petrosian, Ovanes — St. Petersburg State Univ
Gromova, Ekaterina V. — St. Petersburg State Univ

This work is devoted to study cooperative solutions in the games with Looking Forward Approach. LFA is used for constructing game theoretical models and defining solutions for conflict-controlled processes where information about the process updates dynamically. We suppose that during the game players lack certain information about the motion equation and payoff function. At each instant players possess only the truncated information about the game structure. At a given instants information about the game updates, players receive new updated information and adapt. Described model cannot be formulized using classical differential game technics. The new resulting cooperative solution for LFA models is presented and studied.

WeR3A Hotel Hall A

Real-Time Control Problems III (Regular Session)

Chair: Turnau, Andrzej — AGH Univ. of Science and Tech
Co-Chair: Samylovskaya, Anastasia — JSC RPE ``Kvant''

16:10-16:30 WeR3A.1

Dynamically Modified Penalty Function for Control of Mitsubishi Robotic Arm in Real Time, pp. 418-423

Zwonarz, Wojciech — AGH Univ. of Science and Tech
Turnau, Andrzej — AGH Univ. of Science and Tech

An industrial robot-manipulator with six degrees of freedom is considered. The essence is to track a given robot trajectory including detecting and avoiding obstacles in the manipulator's path. The problem of controlling such a robot contains a wide spectrum of issues. The authors focused on the practical aspects of real-time control using simple optical sensors of robot motion. From the software side, the control is based on the penalty function and optimization of the quality criterion. Penalties are generated for errors in position and speed as well as for approaching obstacles. The dynamically modified penalty function becomes a tool for creating variable scenarios of robot maneuvers. Aspects of real-time robot operations are examined and illustrated with the jitter histograms.

16:30-16:50 WeR3A.2

Sign-Definiteness of the Integral Cost on a System of Linear Integral Equations of Volterra Type, pp. 424-427

Samylovskaya, Anastasia — JSC RPE ``Kvant''

We study a question of sign-definiteness of a quadratic cost subject to the system of linear integral equations which has no Legendre term, i.e. is totally degenerate. Therefore, it cannot be studied by the clasical theory of quadratic forms. However, applying some generalizations of the known Goh transform, it is possible to reduce the given functional to a nondegenerate one, and hence, to obtain new necessary conditions of its nonnegativity. Here we reduce the original problem to a form which differs from the “classical” one only by parameter which defines endpoint value of a new control, by using Goh transformation (Goh, 1966). Thus, a new class of problems with reduced cost is investigated and corresponding necessary optimality conditions are obtained.

16:50-17:10 WeR3A.3

Algorithms for the Parametric Optimization of Nonlinear Systems Based on the Conditions of Optimal System, pp. 428-433

Afanas'ev, Valery — National Res. Univ. Higher School of Ec., Moscow Institute of Electronics and Mathematics
Presnova, Anna — National Res. Univ. Higher School of Ec., Moscow Institute of Electronics and Mathematics

The problem of optimal control is formulated for a class of nonlinear objects that can be represented as objects with a linear structure and parameters that depend on the state. The linear structure of the transformed nonlinear system and the quadratic functional of quality allow for the synthesis of optimal control, i.e. parameters of the regulator, move from the need to search for solutions of the Hamilton—Jacobi equation to an equation of the Riccati type with parameters that depend on the state. The main problem of implementing optimal control is related to the problem of finding a solution to such an equation at the pace of object functioning. The paper proposes an algorithmic method of parametric optimization of the regulator. This method is based on the use of the necessary conditions for the optimality of the control system under consideration. The constructed algorithms can be used both to optimize the non-stationary objects themselves, if the corresponding parameters are selected for this purpose, and to optimize the entire managed system by means of the corresponding parametric adjustment of the regulators. The example of drug treatment of patients with HIV is demonstrated the effectiveness of the developed algorithms.

17:10-17:30 WeR3A.4

Solution of Inverse Problems for Control Systems with

Large Control Parameter Dimension, pp. 434-438

Krupennikov, Evgeniy Aleksandrovitch	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The a posteriori analysis of the realized motions (e.g. trajectories and controls) is an important part of the theory of optimal control and decision making. This paper is devoted to solving inverse problems of reconstruction of realized controls for control systems using known inaccurate measurements of the realized trajectories. A new method for solving reconstruction problems is suggested for a class of control systems with dynamics linear in controls and non-linear in state coordinates where the dimension of the control parameter is greater or equal than the dimension of the state variable. This method relies on necessary optimality conditions in auxiliary variational problems. An illustrating example is exposed.

17:30-17:50 WeR3A.5

Optimization of Olive-Oil Extraction Using Nonlinear H-Infinity Control, pp. 439-444

Rigatos, Gerasimos	Industrial Systems Inst
Siano, Pierluigi	Univ. of Salerno
Wira, Patrice	Université d' Haute Alsace
Del Real, Alejandro J.	Univ. of Seville
Giuseppe, Altieri	Univ. of Basilicata

Olive-oil extraction is a process carried out by thousands of small industrial units in the Mediterranean countries (olive-oil mills), often in an empirical manner and using heuristic parametrization. The article proposes a new nonlinear H-infinity control approach for optimizing olive-oil extraction. The state-space model of the olive-oil extraction process is formulated after taking into account time-delays between the control inputs and its outputs. This state-space model undergoes approximate linearization around a temporary operating point which is re-computed at each step of the control method. The linearization is based on Taylor series expansion and on the computation of the model's Jacobian matrices. For the approximately linearized description of the olive-oil extraction system an optimal (H-infinity) feedback controller is designed. The computation of the controller's feedback gain requires the solution of an algebraic Riccati equation which also takes place at each iteration of the control method. The stability properties of the H-infinity control scheme are proven through Lyapunov analysis.

WeR3B Hotel Hall B

Optimization Methods II (Regular Session)

Chair: Miller, Boris	Kharkevich Institute for Information Transmission Problems, RAS
Co-Chair: Sano, Hideki	Kobe Univ

16:10-16:30 WeR3B.1

Control System Design for Visual Positioning of a Ship Based on NMPC and Multi-Objective Structure, pp. 445-450

Sotnikova, Margarita	Saint Petersburg State Univ

The paper is devoted to the area of visual feedback control and the problem of visual dynamic positioning of a ship is considered. It is assumed that the ship is equipped with a camera, through which the necessary information about the objects in 3D world is extracted. The control objective is to provide a given projection of some observable 3D object onto the image plane of the camera. The important feature of the system is that the mathematical model describing its dynamics is essentially nonlinear. The proposed approach to the control system design is based on the nonlinear model predictive control (NMPC) and multi-objective structure of the control law. NMPC is used to calculate the optimal nominal motion on the prediction horizon and the multi-objective structure is applied to design a stabilizing control law in the vicinity of this motion. The obtained results are illustrated by practical example.

16:30-16:50 WeR3B.2

Scalable Real-Time Planning and Optimization Software Complex for the Purposes of Earth Remote Sensing, pp. 451-455

Samylovskiy, Ivan	Moscow State Univ

During this work, a program complex containing specialized libraries, desktop applications and web services is developed for the purposes of Earth remote sensing and managing space shooting orders lifecycle. Complex allows operators and remote clients a functionality to create order for getting Earth images in different modes w.r.t. target satellite ballistic data and shooting technological processes. As a part of complex, libraries to form optimal (in prescribed sense) shooting programs, including flight tasks generation. Software architecture allows users to add new tasks, new shooting modes, new satellites and terrain segment items for perpective earth remote sensing orbital constellations.

16:50-17:10 WeR3B.3

Backstepping Observers for Two Linearized Kermack—McKendrick Models, pp. 456-461

Sano, Hideki	Kobe Univ
Wakaiki, Masashi	Kobe Univ
Maruyama, Hayate	Kobe Univ

In this paper, we consider the problem of constructing observers for two linearized Kermack—McKendrick models. One is a first-order hyperbolic PDE (Partial Differential Equation) model without time lag in the nonlocal boundary condition, and the other contains time lag which expresses latent period. The Kermack—McKendrick model is one of SIR (Susceptible-Infected-Recovered) models, and the linearized equation is often used in early phase of infection. In this paper, we construct an infinite-dimensional observer for each PDE model by using a backstepping approach.

17:10-17:30 WeR3B.4

A Numerical Approach to Joint Continuous and Impulsive Control of Markov Chains, pp. 462-467

Miller, Alexander	Kharkevich Institute for Information Transmission Problems, RAS
Miller, Boris	Kharkevich Institute for Information Transmission Problems, RAS
Stepanyan, Karen	Kharkevich Institute for Information Transmission Problems, RAS

This work considers the continuous and impulse control of the finite state Markov chains in continuous time. In general continuous control governs the transition rates between the states of Markov chain (MC), so the instants and directions of the state changes are random. Meanwhile sometimes there is an urgent necessity to realise the transition which leads to immediate change of the state. Since such transitions need different efforts and produce different effects on the function of the MC itself, one can consider this situation as an impulse control, and if at the same time there is a possibility of graduate control we are coming to the problem of joint continuous and impulse control. In the article we develop the martingale representation of the MC governed by joint continuous and impulse control and give an approach to the solution of the optimal control problem on the basis of the dynamic programming equation. This equation has a form of quasivariational inequality which in the case of finite state MC can be reduced to the solution of the system of ordinary differential equation with one switching line. We give the proof of the verification theorem and find the numerical solution for problems with deterministic and stochastic impulse controls.

17:30-17:50 WeR3B.5

On a Class of Impulsive Control Problems for Continuity Equations, pp. 468-473

Staritsyn, Maxim	Matrosov Inst. for System Dynamics and Control Theory, SB RAS

Pogodaev, Nikolay — Matrosov Inst. for System Dynamics and Control Theory of SB RAS

The talk presents a class of singular control problems for the continuity equation driven by a control-affine vector fields subject to a constraint on the L1-norm of control inputs, ranged in the whole space. Solutions of such distributed systems may occur to be arbitrary close (in a certain natural sense) to discontinuous measure-valued functions, and – as a consequence – related extremal problems are generically ill-posed. In connection with the addressed model, we discuss the following control-theoretical issues: (i) relaxation of the tube of solutions in an appropriate coarse topology; (ii) representation of generalized (discontinuous in time) solutions in terms of continuous arcs through a discontinuous time reparameterization of the characteristic ordinary differential equation, and (iii) a constructive formula for generalized solutions. For the relaxed model, we state an optimal impulsive ensemble control problem and ensure the existence of a minimizer. Finally, we elaborate a conceptual numeric technique for optimal control and exhibit a case study.

WeR3V — Hotel VIP-Hall

Applications in Economics, Management and Environmental Science IV (Regular Session)

Chair: Chistyakov, Sergei — Saint Petersburg State Univ

Co-Chair: Gromova, Ekaterina V. — Saint Petersburg State Univ

16:10-16:30 — WeR3V.1

A System of Models for Constructing a Progressive Income Tax Scale, pp. 474-478

Chistyakov, Sergei — Saint Petersburg State Univ
Uspasskaya, Irina — Saint Petersburg State Univ
Kvitko, Alexandr — Saint Petersburg State Univ
Kichinsky, Dmitry — Lanit-Tercom

This paper considers a system of two mathematical models for constructing an average tax rates scale. The first model with six specified numerical parameters is intended for constructing the average tax rates scale and represents a certain variational game-theoretic model. The second — approximating one — is meant for constructing a marginal tax rates schedule based on the optimal average tax rates scale. It is a problem of the best approximation to the optimal average tax rates schedule by average tax rates scales, and it can be presented in a tabular form traditional for economy.

16:30-16:50 — WeR3V.2

Coalition and Anti-Coalition Interaction in Cooperative Differential Games, pp. 479-483

Gromova, Ekaterina V. — St. Petersburg State Univ
Marova, Ekaterina — St. Petersburg State Univ

This paper is devoted to the study of how the coalition of players interact with the remaining players and vice versa. This is a key question when constructing the characteristic function in cooperative games. In this paper we consider three common approaches to the characteristic function construction in a cooperative differential game of n players: alpha-, delta- and zeta-characteristic functions and introduce a new characteristics of players' behavior termed the reaction measure. Moreover, we introduce a new characteristic function which is technically much easy to construct. We study the properties of all considered characteristic functions and make the conclusion that the new characteristic function can be used instead of the classical alpha-characteristic function. The obtained results are illustrated for a differential game of pollution control.

16:50-17:10 — WeR3V.3

Integral Evaluation of the Investment Effectiveness into Universities Development, pp. 484-489

Tarasyev, Alexandr A. — Ural Federal Univ. Named after the First President of Russia
Sudakova, Anastasiya — Ural Federal Univ. Named after the First President of Russia
Agarkov, Gavriil — Ural Federal Univ. Named after the First President of Russia

In this article we examine the impact of international university rankings on their further development. The answers on questions about the influence of ratings indicators on higher educational institutions, as well as the effectiveness of universities financing in proportion to the position in the rating, were identified. The effectiveness of financial investments in universities when promoting one point in international rankings was calculated using an integrated assessment. Our hypothesis is that due to the achievement of target variables of the rating changes the universities structure: the effectiveness of scientific and innovation activity increases, which leads to an increase in the volume of income from this type of activity. From the point of view of scientific and practical importance, it is possible to group higher education institutions on the basis of the results obtained and allocate funds for them, which will allow achieving target indicators. Thus, this method allows you to evaluate the achievement of maximum results and optimize the funding flow.

17:10-17:30 — WeR3V.4

Dynamic Modeling of Labor Migration between Scientific Organizations, pp. 490-495

Tarasyev, Alexandr A. — Ural Federal Univ. Named after the First President of Russia
Jabbar, Jeenat — Refugee and Migratory Movements Res. Unit (RMMRU)

In this article we examine the processes of academic potential reproduction, taking into account the main threats from scientific migration. Historically, since the 1990-s the amount of researchers in Russian Federation decreased by 58%. Under these conditions it is necessary to estimate the scale of further scientific migration and the outflow of researchers to other spheres of economy. For this purpose we developed a synthetic construction of dynamic models of labor migration and proportional economic growth with two-level optimization. The basis of this model is presented by the classical problem of optimal investments into capital management, expanded by the control unit of total costs directed to the labor resources. This model construction allows us to describe the migration movement between scientific organizations and institutes, taking into account the difference in working conditions. The pricing mechanism in this model is based on the assumption of organization's output maximization at a fixed cost. As result we obtained a multi-level model for the prediction of scientific personnel migratory flows between organizations.

17:30-17:50 — WeR3V.5

Probabilistic Modeling of Passengers and Carriers Preferences Via Bicriterial Approach, pp. 496-498

Timofeeva, Galina — Ural State Univ. of Railway Transport
Martynenko, Alexander — Ural State Univ. of Railway Transport
Zavalishchin, Dmitry — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The problem of modeling preferences of passengers and carriers in conditions of changing the transport network structure is considered. The patterns of passengers and carriers preferences of are formulated on the basis of the bicriterial problem solution. The choice of a route by a random passenger (carrier) is considered as an optimization problem with a random objective function. Forecasting the distribution of traffic flows after changing the structure of the network is carried out within the framework of the Markov chain model. The correspondence matrix of the original network and patterns of passenger preferences are used to estimate the transition probabilities.

ThR1A Hotel Hall A

Differential Games and Control Problems with Uncertainties (Regular Session)

Chair: Andrianova, Olga — MIEM HSE

Co-Chair: Rubinovich, Evgeny — Trapeznikov Institute of Control Sciences, Russian Acad. of Sciences

09:30-09:50 ThR1A.1

Interrelationship of Linear Nonstationary Evasion Problems with Many Evaders, pp. 499-502

Petrov, Nikolai — Udmurt State Univ
Shchelchkov, Kirill — Udmurt State Univ

The evasion problem is considered in which group of pursuers and group of evaders participate under the condition that the pursuers include participants whose capabilities do not yield place to the capabilities of evaders and participants with lesser capabilities. The goal of the group of pursuers is to "catch" all the evaders. The goal of the group of evaders is to prevent this from happening, i.e., to make it possible for at least one of the evaders to avoid an encounter. The pursuers and the evaders employ piecewise-program strategies. It is shown that if in a differential game avoidance of an encounter by at least one evader takes place over an innite time interval, then upon the addition of weak" pursuers avoidance will take place on any nite time interval.

09:50-10:10 ThR1A.2

Two Targets Pursuit-Evasion Differential Game with a Restriction on the Targets Turning, pp. 503-508

Rubinovich, Evgeny — Trapeznikov Institute of Control Sciences, Russian Acad. of Sciences

The differential game under consideration belongs to the class of pursuit-evasion games in which pursuers are less than targets. Namely, the differential game of one pursuer against a coalition of two coherently dodging targets, one of which is false, is considered on the plane. The probabilities of targets classification are given. The pursuer has a simple motion. Each of the targets has a restriction on the minimum allowable turning radius. The main criterion is the mathematical expectation of the distance to the true target at a terminal point in time that is not fixed in advance and chosen by the pursuer during the pursuit process. The saddle point of the game in program and positional strategies was found. Illustrative examples are given.

10:10-10:30 ThR1A.3

Optimality Conditions with Feedback Controls for Optimal Impulsive Control Problems, pp. 509-514

Samsonyuk, Olga — Matrosov Inst. for Systems Dynamics and Control Theory SB RAS
Dykhta, Vladimir — Inst. for System Dynamics and Control Theory SB RAS

This paper concerns with optimal impulsive control problems with trajectories of bounded variation. Necessary optimality conditions based on weakly monotone solutions of the Hamilton—Jacobi inequality and feedback controls are discussed. A particular attention is paid to necessary optimality conditions with feedback controls, called Feedback minimum principle. The latter is generalized the corresponding principle for classical optimal control problems and is formulated in terms of Pontryagin Maximum Principle. An example illustrating these results is considered.

10:30-10:50 ThR1A.4

Robust Anisotropy-Based Control for Uncertain Descriptor Systems with Transient Response Constraints, pp. 515-520

Andrianova, Olga — MIEM HSE
Belov, Alexey A. — ITMO Univ

In this paper, a problem of robust anisotropy-based control with regional pole assignment for descriptor systems with norm-bounded parametric uncertainties is considered. The goal is to find a state-feedback control law, which guarantees desirable disturbance attenuation level from stochastic input with unknown covariance to controllable output of the closed-loop system, and ensures, that all finite eigenvalues of the closed-loop system belong to the given region inside the unit disk for all uncertainties from the given set.

ThR1B Hotel Hall B

Multi-Objective Control and Optimization I (Regular Session)

Chair: Polovinkin, Evgenii — Moscow Inst. of Physics and Tech

Co-Chair: Khrustalev, Mikhail — V. A. Trapeznikov Inst. of Control Sciences of Russian Acad. of Sciences

09:30-09:50 ThR1B.1

Necessary Optimality Conditions for the Mayer Problem with Unbounded Differential Inclusion, pp. 521-524

Polovinkin, Evgenii — Moscow Inst. of Physics and Tech

In this paper, we consider the differential inclusion with unbounded right-hand side and with local conditions called conditions of measurable pseudo-Lipschitz mappings, which were proposed by the author. In these works, under the conditions of measurable pseudo-Lipschitz right-hand side of the differential inclusion many results were received, namely: existence theorem for solutions, theorem on the relaxation of differential inclusion, theorem on the differentiation of the initial data and other properties of trajectorys of differential inclusion with unbounded right-hand side. We consider a differential inclusion with conditions that are very closed to that introduced by Clarke.

Necessary conditions incorporating the Euler—Lagrange inclusion are put forward. Our results weaken the hypotheses and strengthen the conclusions of the previously available works—they allow the admissible velocity sets to be unbounded and nonconvex under a certain pseudo-Lipschitz hypothesis.

The preset paper continues the study of the direct method, which was proposed by the author . This direct method is a development of the classical method of variations underlying the Pontryagin maximum principle for classical optimal control problems. The first steps of developing the Pontryagin's direct method to optimization problems involving differential inclusions were made in the works of B.Pshenichnyi (1980), V.Blagodatskikh (1986) and others. In this way we prove necessary optimality conditions incorporating the Euler—Lagrange inclusion with no use of the Clarke normal cone or the limiting normal cone.

09:50-10:10 ThR1B.2

Synthesis of Adaptive Control Strategies for Flocks of Mobile Robots Using Aristotle's Mechanics, pp. 525-529

Khrustalev, Mikhail — V. A. Trapeznikov Inst. of Control Sciences of Russian Acad Sci

We propose an Aristotle's mechanics based method for synthesis of analytic control strategies for a flock of unmanned mobile robots. Synthesized strategies ensure bypass prohibited areas, non-collision of elements in the flock, preservation of the flock integrity, and fulfillment of the common goal.

10:10-10:30 ThR1B.3

Cooperation in Dynamic Multicriteria Games, pp. 530-533

Rettieva, Anna — Inst. of Applied Mathematical Res., Karelian Res. Centre

The new approaches to construct equilibria in dynamic multicriteria games with finite planning horizon are presented. We consider a dynamic, discrete-time game model where the players use a common resource and have different criteria to optimize. The multicriteria Nash equilibrium is obtained via the Nash bargaining design (Nash products), and the cooperative equilibrium is determined by the Nash bargaining procedure for the entire planning horizon. Furthermore, the suggested approach is applied to determine cooperative strategies and payoffs for any coalition to be formed. Dynamic multicriteria bioresource management problem with finite harvesting times is considered. The players' strategies and the size of the resource are compared under cooperative and noncooperative behavior.

10:30-10:50 ThR1B.4

Optimal Placement and Tuning Approach for Design of Power System Stabilizers and Wide Area Damping Controllers Considering Transport Delay, pp. 534-539

Matsukawa, Yoshiaki — Kyushu Inst. of Tech
Watanabe, Masayuki — Kyushu Inst. of Tech
Takahashi, Hibiki — Kyushu Inst. of Tech
Mitani, Yasunori — Kyushu Inst. of Tech

In this paper, a novel optimal placement and parameter tuning approach for Power System Stabilizer (PSS) is proposed to damp both local and inter-area modes in mesh like power system. The design target is two-level PSS consisting of ΔP type local PSS and Δθ type Wide Area Damping Controller (WADC). For the PSS placement, modeshape with eigenvector sensitivity and coherency analysis are used to determine the appropriate placement of both local PSS and WADC. For the PSS parameter tuning, metaheuristics based approach via Mean Variance Mapping Optimization (MVMO) is employed in order to consider the time domain analysis. The proposed objective function designs at first the local PSS only to improve damping coefficient and damping ratio of eigenvalue. After that, it designs the WADC overlapping with already designed local PSS by time domain analysis, taking into account the transport delay in the remote signal between Phasor Measurement Unit (PMU) and PSS. The proposed method is applied in IEEE New England 39-Bus (NE 39-bus) system model. Then, modeshape and coherent grouping analysis give us understandable system aspect, the local PSS and the WADC optimized by using MVMO considering the transport delay improve both local and inter-area modes whereas a method ignoring the transport delay make system poorly damped.

ThR1V Hotel VIP-Hall

Stochastic Optimization I (Regular Session)

Chair: Ryashko, Lev — Ural Federal Univ
Co-Chair: Chernyshov, Kirill — V.A. Trapeznikov Inst. of Control Sciences, RAS

09:30-09:50 ThR1V.1

Stochastic Control in the Problem of Preventing Ecological Catastrophes, pp. 540-544

Ryashko, Lev — Ural Federal Univ

A problem of the analysis and prevention of catastrophic shifts in stochastically forced ecosystems is considered. For the solution of this problem, a new mathematical approach based on the analysis and synthesis of the stochastic sensitivity of dynamic regimes in population models is suggested. Technical details of this approach are discussed for the conceptual stochastically forced Bazykin—Berezovskaya predator-prey model with the Allee effect. For this population model, a phenomenon of the noise-induced extinction is analysed by the method of confidence domains. By reducing these domains we provide a stabilization of the persistence regime for both interacting species.

09:50-10:10 ThR1V.2

Stochastic Analysis and Control in Kinetics of Multistable Chemical Reactor, pp. 545-549

Bashkirtseva, Irina — Ural Federal Univ
Pisarchik, Alexander N. — Centro De Investigaciones En Optica

We consider a model of thermochemical reactor proposed by Nowakowski. Stochastic effects in the bistability zone are studied. A parametric analysis of noise-induced transitions between coexisting equilibria is carried out on the basis of the stochastic sensitivity technique and confidence ellipses method. We solve the problem of stabilization of the equilibrium regime under incomplete information. The feedback regulator which reduces the stochastic sensitivity and stabilizes the randomly forced equilibrium is constructed.

10:10-10:30 ThR1V.3

Constructing a Symmetric Tsallis Divergence As a System Identification Criterion, pp. 550-555

Chernyshov, Kirill — V.A. Trapeznikov Inst. of Control Sciences, RAS

In spite of the system identification, as (in accordance to L. Ljung (2010)) a science and art of constructing mathematical models via sample data, is a polyhedral process, selecting an identification criterion within an identification problem statement is a constituent part requiring both accounting its adequacy to the data available and practical suitability of implementation. The paper presents an approach to the identification of input/output mappings of stochastic systems in accordance to information-theoretic criteria that are derived by constructing a symmetric divergence measure based on Tsallis entropy of an arbitrary order. Meanwhile, a parameterized description of the system under study is utilized combined with a corresponding technique of estimation of the mutual information constructed by use of Tsallis entropy. This leads, finally, to a problem of the finite dimensional optimization to be solved by a suitable technique.

10:30-10:50 ThR1V.5

Non-Quadratic Optimization and Adaptive Robust Filtering, pp. 556-561

Chernodarov, Alexander — “NaukaSoft” Experimental Lab. Ltd

The solution of this problem is based on the combination of the possibilities of adaptive robust and guaranteeing techniques for signal processing. The proposed technique relies on the theory of multilevel optimization of stochastic systems on the basis of non-classical cost functions. This technique includes the following: the key parameter is formed for the first level of optimization, which characterizes the accuracy of estimation; the generalized parameter is formed, which characterizes the reliability of estimation; tolerances on the generalized parameter are specified; the likelihood function is formed, which includes the parameters of the first and second levels of optimization; using the maximum principle technique and the method of invariant imbedding, the two-point boundary-value problem is solved. The algorithms synthesized for adaptive robust data processing with guaranteeing tuning from the generalized parameter is shown.Results of the mathematical simulation are given.

ThR2A Hotel Hall A

Control Algorithms (Regular Session)

Chair: Melnikov, Nikolai — Lomonosov Moscow State Univ
Co-Chair: Tsyganova, Julia — Ulyanovsk State Univ

11:20-11:40 ThR2A.1

Parallel Parameter Optimization Algorithm in Dynamic General Equilibrium Models, pp. 562-567

Gruzdev, Arseniy — Lomonosov Moscow State Univ

Melnikov, Nikolai	Lomonosov Moscow State Univ
Dalton, Michael	National Oceanic and Atmospheric Administration
Weitzel, Matthias	European Commission, Joint Res. Centre
O'Neill, Brian	National Center for Atmospheric Res

We present a parallel parameter optimization algorithm for reproducing future projections of certain model outputs in dynamic general equilibrium models. The optimization problem is reduced to a nonlinear system of equations. The Jacobian matrix for a Newton-type solver in the problem is generated in parallel. The parameter optimization algorithm is implemented for parallel systems with distributed memory by using MPI. To achieve better performance of the parallel algorithm we use the parallel Fair—Taylor algorithm for computing an equilibrium path. Calculation of prices, input-output ratios and international trade for different time steps is carried out in parallel at each iteration of the method. The solution method is implemented for parallel systems with shared memory by using OpenMP. The effectiveness of the hybrid MPI+OpenMP parallel code for parameter optimization is demonstrated in the example of a global multi-sector energy economics model with scenarios that are used for studying climate change impacts on land use.

11:40-12:00 ThR2A.2

Numerically Efficient LD-Computations for the Auxiliary Performance Index Based Control Optimization under Uncertainties, pp. 568-573

Semushin, Innokentiy Vassily	Ulyanovsk State Univ
Tsyganova, Julia	Ulyanovsk State Univ
Tsyganov, Andrey	Ulyanovsk State Pedagogical Univ. Named after I.N. Ulyanov

This paper addresses the problem of numerically ecient computations for the auxiliary performance index (API) based linear time-variant stochastic models optimization. The main result of the paper is the new algorithm for numerically efficient (i.e. robust against round-off errors) array LD-computations for the API and its gradient.

12:00-12:20 ThR2A.3

Identification of Linear Models by Fuzzy Basis Functions, pp. 574-579

Demenkov, Nikolay	Bauman Moscow State Tech. Univ
Mikrin, Evgeny	Bauman Moscow State Tech. Univ
Mochalov, Ivan	Bauman Moscow State Tech. Univ

This article reviews the application of the least squares method for the processing of hybrid data. We formulated and solved the problem of fuzzy estimation of the parameters of a model with fuzzy basis functions, during the solution of which fully fuzzy systems of linear equations appear. In order to illustrate the solution of the problem by the inverse matrix method, two fuzzy basis functions are reviewed: fuzzy unit and fuzzy linear dependence.

12:20-12:40 ThR2A.4

Identification of Fractional Linear Dynamical Systems with Autocorrelated Errors in Variables by Generalized Instrumental Variables, pp. 580-584

Ivanov, Dmitriy	Samara State Univ. of Transport
Sandler, Ilya	Samara State Univ. of Transport
Kozlov, Evgeny	Samara State Univ. of Transport

This paper addresses the problem of identifying stochastic linear fractional discrete-time systems from noisy input/output data. The input noise is supposed to be fractional noise, while the output noise is as-sumed colored or fractional noise. The paper also proposes an estimator based on the generalized in-strumental variables estimator. We have compared the proposed estimator with other estimators with the help of Monte Carlo simulations. The results of the simulated examples indicate that the proposed esti-mator provides good accuracy.

ThR2B Hotel Hall B

Multi-Objective Control and Optimization II (Regular Session)

Chair: Petrosyan, Leon	Saint Petersburg Univ
Co-Chair: Ushakov, Vladimir	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

11:20-11:40 ThR2B.1

The Two Level Cooperation in a Class of N-Person Differential Games, pp. 585-587

Petrosyan, Leon	Saint Petersburg Univ
Yeung, David W.-K.	Hong Kong Shue Yan Univ

In this paper, we consider a coalitional partition of a set of players, N, in which each coalition $S_i \subset N$, $i \in 1,...,m$ $(S_i \cap S_i = \emptyset)$, $i \neq j$ of players plays against the other coalitions in a non-zero sum cooperative differential game with prescribed duration and non-transferable payoffs. At the same time players within a coalition play a cooperative differential game with prescribed duration and transferrable utility. The solution concept for such type of differential games is proposed and its properties, namely time-consistency or dynamic stability, investigated.

11:40-12:00 ThR2B.2

Chattering-Free Fixed-Time Control for Bilateral Teleoperation System with Jittering Time Delays and State Constraints, pp. 588-593

Wang, Ziwei	Tsinghua Univ
Liang, Bin	Tsinghua Univ
Wang, Xueqian	Tsinghua Univ

In this work, a new adaptive control scheme is presented for a class of bilateral teleoperation system with system uncertainties, jittering time delays, and state-constraint problem. A fixed-time control strategy with a novel proposed exponential-type Barrier Lyapunov Function (EBLF) is incorporated to achieve fixed-time convergence with state error constraints through the “adding a power integrator” technique and the full-order sliding mode method. During the sliding motion, the system behaves as a desirable full-order dynamics rather than a reduced-order dynamics. The singularity phenomena and chattering problem are avoided while fixed-time convergence without violation of full-state constraints is guaranteed. Simulation results further demonstrate the effectiveness of the proposed method.

12:00-12:20 ThR2B.3

Algorithms for Constructing Optimal Packing into Ellipses, pp. 594-599

Lebedev, Pavel	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Ushakov, Vladimir	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Lavrov, Nikita	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

In control problems, it is often required to approximate sets by collections of congruent elements. One of the ways of this approximation is packing a collection of circles of equal radius into figures on a plane. This paper presents two variants of the problem of constructing optimal packing into ellipses of various shapes: in the first variant the number of elements is fixed and it is required to maximize their radius, in the second one the radius of circles is fixed and it is required to maximize their number. Iterative methods simulating the repulsion of centers of the circles from each other and from the boundary of the set are applied in the first variant. Constructions of the Chebyshev center, orthogonal projections and repulsion of points are used in these methods. Near-optimal packing with a hexagonal

lattice are considered in the second variant. The software package for construction of packing for eclipses with various axial ratios has been developed.

12:20-12:40 ThR2B.4

A Fuzzy Generalized Simulated Annealing for a Simple Assembly Line Balancing Problem, pp. 600-605

Lalaoui, Mohamed	ENSIAS – Mohammed V Univ
EL Afia, Abdellatif	ENSIAS – Mohammed V Univ

The assembly line is generally known as the last stage of the production processes. It constitutes the main production paradigm of the manufacturing industry. Thus, the performance of the assembly line problem has an important impact on the global performance of the entire production system. Among others, due to demand rate fluctuation. It's important to quickly rebalance the assembly line and obtain an effective solution for ALB problem. For these reasons, this article proposes an adaptive generalized simulated annealing using fuzzy inference system to solve simple assembly line balancing problem of type I (SALBP-I). The objective of the problem is to minimize the number of stations for a predefined cycle time of workstations in an existing assembly line. Moreover, the performance of our approach is analyzed using a well-known data set of the SALBP-I.

ThR2V Hotel VIP-Hall

Stochastic Optimization II (Regular Session)

Chair: Bashkirtseva, Irina	Ural Federal Univ
Co-Chair: Loparev, Alexei	Concern CSRI Elektropribor, JSC

11:20-11:40 ThR2V.1

Regularization in the Problem of Minimization of Stochastic Sensitivity, pp. 606-609

Ryashko, Lev	Ural Federal Univ
Bashkirtseva, Irina	Ural Federal Univ

We consider a problem of the construction of feedback regulator which synthesizes an assigned stochastic sensitivity of the equilibrium in stochastically forced nonlinear dynamic system. In the case of complete information, it is shown that this problem can be reduced to the solution of the matrix algebraic equation. A presence of noise in measurements deforms the stochastic sensitivity. We find conditions when such deformation is extremely large, and the considered problem is ill-posed. For this ill-posed problem, a regularization method is suggested. We propose an analytical approach which allows us to take into account a presence of noise in measurements when we construct an optimal feedback regulator. General theoretical results are illustrated by examples.

11:40-12:00 ThR2V.2

Stochastic Sensitivity Synthesis in Discrete-Time Systems with Parametric Noise, pp. 610-614

Bashkirtseva, Irina	Ural Federal Univ

Discrete nonlinear stochastic systems with general parametric noises are considered. To approximate the dispersion of random states, we propose an asymptotic approach based on the stochastic sensitivity analysis. This approach is used for the solution of the stabilization problem for the discrete controlled systems forced by parametric noise. A theory of the synthesis of the stochastic sensitivity by the feedback regulators is elaborated. Regulators minimizing the stochastic sensitivity are used in the problem of the structural stabilization of equilibrium regimes in population dynamics. The efficiency of this technique is demonstrated on the example of the suppression of undesired noisy large-amplitude regular and chaotic oscillations in the Hassell population model.

12:00-12:20 ThR2V.3

Rough Paths Theory and Impulsive Control: A Promising Connection, pp. 615-618

Samsonyuk, Olga	Matrosov Inst. for Systems Dynamics and Control Theory, SB RAS
Staritsyn, Maxim	Matrosov Inst. for System Dynamics and Control Theory, SB RAS

This short discussion note is devoted to establishing some connections between the framework of dynamical systems driven by signals of a low regularity (rough differential equations) and the mathematical theory of impulsive control (measure-driven systems), which, as we believe, would essentially enrich one another. More precisely, we attempt to elaborate an impulsive (discontinuous) extension of the theory of rough differential equation for input-affine models with states of unbounded first variation. In the paper, we are focused on a concept of solution for impulsive rough differential equations with vector-valued controls of bounded p-variation, $p \in (1,2)$, and its constructive representation through a discrete-continuous Young's integral equation.

12:20-12:40 ThR2V.4

Polynomial Filtering Algorithm for Single-Beacon Navigation Problem, pp. 619-623

Toropov, Anton	Central Scientific Res. Inst. Elektropribor
Stepanov, O.A.	Concern CSRI Elektropribor, JSC; Univ. ITMO
Basin, Michael V.	Autonomous Univ. of Nuevo Leon
Vasilyev, Vladimir	State Res. Center of the Russian Federation Concern CSRI Elektropribor
Loparev, Alexei	Concern CSRI Elektropribor, JSC

A polynomial filtering algorithm is proposed to solve a sea vehicle navigation problem using information on the range and radial velocity with respect to a fixed beacon, formulated in the context of the Bayesian approach. An example of practical implementation of the designed algorithm is considered. It is shown that the accuracy of the polynomial algorithm is close to that calculated by method of statistical tests with the use of a particle filter; in comparison, the Extended Kalman filter (EKF) yields a worse result.

ThR3A Hotel Hall A

Optimal Control VI (Regular Session)

Chair: Sesekin, Alexander	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Co-Chair: Kumkov, Sergey I.	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

14:20-14:40 ThR3A.1

Analysis of Economic Growth Models Via Value Function Design, pp. 624-629

Bagno, Alexander	Ural Federal Univ
Tarasyev, Alexander M.	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

Properties of the value function are examined in an infinite horizon optimal control problem with an unlimited integrand index appearing in the quality functional with a discount factor. Optimal control problems of such type describe solutions in models of economic growth. Necessary and sufficient conditions are derived to ensure that the value function satisfies the infinitesimal stability properties. It is proved that value function coincides with the minimax solution of the Hamilton—Jacobi equation. Description of the growth asymptotic behavior for the value function is provided for the logarithmic, power and exponential quality functionals. An example is given to illustrate construction of the value function in economic growth models.

14:40-15:00 ThR3A.2

Optimal Controlled Descent in the Atmosphere and the

Modified Brachistochrone Problem, pp. 630-635

Cherkasov, Oleg	Moscow Lomonosov State Univ
Zarodnyuk, Alena	Lomonosov Moscow State Univ

The problem of maximization of the horizontal coordinate and minimization of the fuel expenditures of mass-point moving in the vertical plane driven by gravity, linear and quadratic viscous drag, and thrust is considered. The slope angle and the thrust are considered as a control variables. The problem is related to the modified brachistochrone problem. Principle maximum procedure allows to reduce the optimal control problem to the boundary value problem for a set of systems of two nonlinear differential equations. Thrust control depending on the velocity and slope angle is designed. Thus, the structure of optimal synthesis and the qualitative behavior of the optimal trajectories are investigated by means of methods of the theory of dynamical systems. The extremal synthesis of the thrust is designed. It is established that the extreme thrust control program consists either of single arc with intermediate thrust control, or two arcs, starting with maximum thrust and ending with the intermediate thrust or three arcs: ”intermediate-maximum-intermediate”.

15:00-15:20 ThrR3A.3

Optimal Control of the Fuel Reload Mechanism, pp. 636-641

Dolgii, Yurii F.	Ural State Univ
Sesekin, Alexander	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Tashlykov, Oleg	Ural Federal Univ
Zaynullina, Elvira	Ural Federal Univ

The algorithm for determining the optimal route for moving and controlling the mechanisms for reloading fuel assemblies of fast neutron reactors is proposed. It allows increasing the efficiency of the Nuclear Power Plant operation by reducing the stopping time for nuclear fuel transhipment.

15:20-15:40 ThR3A.4

Non-Conflict Air Traffic Control in Flight-Path Straightening Operations, pp. 642-647

Kumkov, Sergey I.	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Pyatko, Sergey G.	NITA LLC
Ovchinnikov, Mikhail M.	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

Increasing the density of aircraft traffic and complication of schemes of the air traffic control (ATC) create difficulties for the air traffic control operator to make “by-hands” decisions for organization of non-conflict motions and providing their optimality on some criteria. Under this, the operator needs fore-handed analysis of his possible decisions and recommendations (from the automated ATC System) for detecting and solving possible conflict situations (of dangerous closing or approach). The paper is devoted to elaboration of algorithms of using the procedures for straightening the aircraft flight-paths w.r.t. its previous flight plan trajectories. Possible induced conflict situations are detected and necessary recommendations for their exclusion are given.

ThR3B Hotel Hall B

Optimization under Uncertainties Including the Theory of Noise Measurements I (Regular Session)

Chair: Granichin, Oleg	Saint Petersburg State Univ
Co-Chair: Averboukh, Yurii	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

14:20-14:40 ThR3B.1

Comparison of Multi-Sensor Task Assignment Methods: Linear Matrix Inequalities vs. Brute Force, pp. 648-653

Erofeeva, Victoria	Saint Petersburg State Univ
Granichin, Oleg	Saint Petersburg State Univ
Leonova, Anna	Saint Petersburg State Univ

Due to significant advancements in embedded systems, sensor devices and wireless communication technology, sensor networks have been attracting widespread attention in areas such as target tracking, monitoring, and surveillance. Technological advancements made it possible to deploy a large number of inexpensive but technically advanced sensors to cover wide areas. However, when a tracking system has to track a large number of targets, the computation and communication loads arise. In this paper we compare two task assignment methods that might be used in the multiple target tracking problem. The first one is the brute force method and the second one is based on linear matrix inequalities. We provide performance and load testing results for these methods.

14:40-15:00 ThR3B.2

Target Problem for Mean Field Type Differential Game, pp. 654-658

Averboukh, Yurii	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The paper is concerned with the mean field type differential game that describes the behavior of the large number of similar agents governed by the unique decision maker and influenced by disturbances. It is assumed that the decision maker wishes to bring the distribution of agents onto the target set in the space of probabilities within the state constraints. The solution of this problem is obtained based on the notions u- and v-stability first introduced for the finite dimensional differential games.

15:00-15:20 ThR3B.3

Localization with Several Instants of Signal Transmission in Multilateration Systems, pp. 659-662

Bedin, Dmitrii	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The problem of object localization in multilateration systems is considered in the case when measurements (times of arrival, or TOA) of several consecutive signal transmissions are processed together. The suggested solution of the problem is based on minimization of the sum of residuals between TOA and their model. We proposed an effective numerical method for this optimization task, which accuracy is close to the Cramer-Rao lower bound for the corresponding observation equations. The results of work of the algorithm on simulated data with real locations of the receiving stations are presented.

15:20-15:40 ThR3B.4

Frequency Estimation of a Sinusoidal Signal with Time-Varying Amplitude and Phase, pp. 663-668

Vedyakov, Alexey	ITMO Univ
Vediakova, Anastasiia	Saint Petersburg State Univ
Bobtsov, Alexey	ITMO Univ
Pyrkin, Anton	ITMO Univ
Kakanov, Mikhail	ITMO Univ

This paper is devoted to frequency estimation of a non-stationary sinusoidal signal. The amplitude is supposed to be a known function within a constant factor, the phase should be known. Example of such problem statement is sensorless angular velocity estimation for permanent magnet synchronous motors. On the first step by reparametrization, a third order linear regression model is obtained. On the next step, an estimation algorithm is constructed based on a standard gradient approach. The frequency estimate can be computed from one of the model parameters using inverse trigonometric functions. To improve estimates quality for noisy measurements we propose a new identification method, which can be tuned to attenuate the noise influence. It is shown that the frequency estimation error converges to zero exponentially fast. The described algorithm does not require measuring or calculating derivatives of the input signal. The efficiency of the

proposed approach is demonstrated through the set of numerical simulations.

ThR3V Hotel VIP-Hall

Control of Partial Differential Equations I (Regular Session)

Chair: Plekhanova, Marina — South Ural State Univ

Co-Chair: Dryazhenkov, Andrey Alexandrovich — Faculty of Computational Mathematics and Cybernetics, Lomonosov Moscow State Univ

14:20-14:40 ThR3V.1

Optimal Control Existence for Degenerate Infinite Dimensional Systems of Fractional Order, pp. 669-674

Plekhanova, Marina — South Ural State Univ

Optimal control problems solvability are researched for infinite dimensional control systems, described by semilinear evolution equations in Banach spaces with degenerate linear operator at the Caputo fractional derivative. The pair of linear operators in the equation is relatively bounded and the nonlinear operator satisfies some smoothness conditions, in particular the condition of uniform Lipschitz continuity, and one of two types additional conditions: independence of degeneracy subspace elements or non-belonging of the operator image to the degeneracy subspace. The control system is endowed by the generalized Showalter—Sidorov initial conditions, which are natural for degenerate evolution equations. Optimal control have to belong to a convex closed set of admissible controls and to minimize a convex, bounded from below, lower semicontinuous and coercive cost functional. Solvability conditions are found for the optimal control problem of this class. If the existence of the initial problem solution with an admissible control is obvious, it is shown that the local Lipschitz continuity in phase variables that uniform with respect to time is sufficient for the optimal control existence. Abstract results are illustrated by optimal control problem for the equations system of the fractional viscoelastic Kelvin—Voigt fluid dynamics.

14:40-15:00 ThR3V.2

Approximate Controllability of Strongly Degenerate Fractional Order System of Distributed Control, pp. 675-680

Fedorov, Vladimir — Chelyabinsk State Univ

Gordievskikh, Dmitriy — Shadrinsk State Pedagogical Univ

The approximate controllability of a class of infinite dimensional control systems, described by the equation not solved with respect to the fractional Caputo derivative, is studied. Under the supposition of relative p-boundedness of the pair of operators in the equation the control system is reduced to two subsystems on mutually complement subspaces. One of subsystem is solved with respect to the fractional derivative, another subsystem has a nilpotent operator at the derivative. It is proved the equivalence of the approximate controllability of the original system and of every of two subsystems by the same control. This fact applied to the deriving of a criterion of the approximate controllability of the degenerate control system after research of every subsystem approximate controllability conditions. Application of the criterion is demonstrated on an example of a system described by partial differential equations.

15:00-15:20 ThR3V.3

Construction of Singular Sets in a Velocity Control Problem with Nonconvex Target, pp. 681-686

Lebedev, Pavel — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

Uspenskii, Alexander — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The problem of occurrence of singular sets of solution of the velocity control problem for one class of dynamic problems on a plane with a nonconvex target set is studied. The theoretical apparatus is developed for determining pseudo-vertices of a target set in case when its boundary is a curve with a minimum order of smoothness. Finding pseudo-vertices is a necessary element of the procedure for constructing branches of the singular set of the optimal result function. Necessary conditions for the existence of pseudo-vertices, expressed in terms of one-sided partial limits of differential relations dependent on properties of local diffeomorphisms that determine these singular points, are obtained. Examples of constructing a nonsmooth solution to the velocity control problem are given. The developed procedures for determining the disturbance of smoothness of the solution to the dynamic control problem are also applicable when constructing generalized solutions of Hamilton—Jacobi type equations, as well as when forming a generalized eikonal in geometrical optics.

15:20-15:40 ThR3V.4

Numerical Solution to the Positional Boundary Control Problem for the Wave Equation with Unknown Robin Coefficients, pp. 687-691

Dryazhenkov, Andrey Alexandrovich — Faculty of Computational Mathematics and Cybernetics, Lomonosov MSU

A boundary control problem for the one-dimensional wave equation is considered. The goal of the closed-loop control is to bring the system from the unknown initial state to the rest state. The main specificity of the problem is the assumption that the coefficients from Robin boundary conditions are unknown and must be indentified using additional boundary information on the controlled side of the space interval. In the paper a method for numerical solution of this problem is proposed. The method is a combination of the method developed previously for the case of known boundary coefficients and a special identification procedure based on smoothness analysis.

ThR4A Hotel Hall A

Optimal Control VII (Regular Session)

Chair: Pogodaev, Nikolay — Matrosov Inst. for System Dynamics and Control Theory of Siberian Branch of Russian Acad. of Sciences

Co-Chair: Tsyganov, Vladimir — Inst. of Control Sciences Russian Acad. of Sciences

16:10-16:30 ThR4A.1

Application of Minimax Filtration Using Non-Linear Model for Evaluation of Motion Parameters of Unmanned Aerial Vehicle, pp. 692-697

Tolpegin, Oleg — BSTU VOENMEH

Minimax filtering algorithm based on approximation of the information sets and reachability ones by parallelepipeds guaranteed to contain exact values of the measured parameters is considered. To calculate the parallelepipeds, approximating the reachability set of the high-speed aircraft, it is proposed to use the non-linear system of differential equations. The results of filtration are given for various unknown program controls of an unmanned aerial vehicle.

16:30-16:50 ThR4A.2

Optimization of Transport Monopoly Control, pp. 698-703

Tsyganov, Vladimir — Inst. of Control Sciences, Russian Acad. of Sciences

A hierarchical model of a large-scale system including a control Centre and a transport monopoly is considered. The mechanism of control of the transport monopoly is defined. The decisions of the game of monopoly with the control Centre are considered. The task of the optimal synthesis of the control mechanism is set. Sufficient conditions for the optimality of this mechanism are found when driving vehicles

along a ring road with a prohibited overtaking (for example, by rail or a single-lane highway). The cases of the optimal balance of supply and demand, as well as scarce demand are considered. For the case of excessive demand, sufficient conditions for the optimality of the number of vehicles and the carrying capacity have been determined. Some conditions for the optimality of control mechanisms for road and rail transport have been found.

16:50-17:10 ThR4A.3

Minimum Time Function of a Non-Autonomous Control System, pp. 704-707

Pogodaev, Nikolay — Matrosov Inst. for System Dynamics and Control Theory of SB RAS
Voronov, Vsevolod — ISDCT SB RAS

For a time-dependent control system we consider a "reversed" minimum time problem, which consists in finding the minimum time needed by the system, whose state is initially located in a given set, to reach a given point. We show that the minimum time function constructed in this way is a unique viscosity solution of a static first order PDE, provided that, at every point of the extended phase space, admissible velocities form a convex set containing zero in the interior. We also describe a version of the Fast Marching Method (FMM) that effectively solves this PDE.

17:10-17:30 ThR4A.4

On the Minimization of a Degenerate Quadratic Functional, pp. 708-711

Parilova, Natalia — Moscow State Univ
Dmitruk, Andrei — Russian Acad. of Sciences, Central Ec. and Mathematics Inst

On the linear control system, we consider an integral quadratic functional with a degenerate coefficient at the square of control. The problem is to find its minimum under a given initial value of the state variable and a free terminal value, which comes into the terminal part of the functional. Using a change of variable, the so-called Goh transformation, a passage to a new control and thus to an extended space of admissible controls is performed. Rewritten in the new variables, the functional may be now nondegenerate, i.e., may satisfy the strengthened Legendre condition with respect to the new control. Assuming the positive definiteness of the transformed functional for zero initial state value, we prove the existence of its minimum for any initial values of the state variable and then show that this minimum is a quadratic form of the initial value, the matrix of which satisfies the corresponding Riccati equation. It is also proved that the minimum of the transformed functional is equal to the infinum of the initial one, and a minimization sequence for the later one is constructed.

17:30-17:50 ThR4A.5

Two-Stage Workflow Control with a Predictive Component, pp. 712-716

Vladova, Alla — Trapeznikov Institute of Control Sciences, Russian Acad. Sci
Vladov, Jury — Orenburg State Univ

Background. Despite the wide use of controllers with proportional-integral-differential control law (PID controllers), the issue of expanding the limited functionality of not taking into account the trend of changing technological parameters is open. Methods. The control action is formed taking into account the predicted value of the technological parameter. Verification. The proposed method is verified for the reactor that processes the waste gases in sulfur production. Conclusions. Using a PID controller with a predictive component significantly improves the quality of control, reduces the maximum deviations of process parameters from specified values, contributing to additional energy saving and a significant increase in the efficiency of automated process units in the oil and gas industry and mechanical engineering.

ThR4B Hotel Hall B

Optimization under Uncertainties Including the Theory of Noise Measurements II (Regular Session)

Chair: Ledyaev, Yuri — Western Michigan Univ
Co-Chair: Surkov, Platon — N.N. Krasovskii Inst. of Mathematics and Mechanics (IMM UB RAS)

16:10-16:30 ThR4B.1

To the Problem of Adaptive Guaranteed Estimation, pp. 717-722

Shiryaev, Vladimir — South Ural State Univ (National Res. Univ)
Khadanovich, Dina — South Ural State Univ (National Res. Univ)

The article deals with linear dynamical system state estimation problem under uncertainty when disturbance and measurement error statistics are unknown but the sets of their possible values are available. The approach to adaptive algorithm development of guaranteed estimation is proposed. The approach is based on the processing of innovation sequence values in the Kalman filter under conditions of a small number of available measurements. The Kalman filter implementation is performed for measurement data preprocessing the result of which is the mathematical model development and refining the estimates of unknown measurement errors.

16:30-16:50 ThR4B.2

Program-Predictive Feedback Control for Systems with Evolving Dynamics, pp. 723-726

Ledyaev, Yuri — Western Michigan Univ

In this talk we discuss an approach for analysis of new class of optimal control problems under uncertainty. A particular case of such problem is the control system which dynamics is evolved in accordance with one of the possible scenarios of changing of parameters of the system. A bifurcating nature of these scenarios requires a use of non-anticipating (causal) control strategies or feedback controls.

We describe optimization theory of characterization of such optimal non-anticipating strategies. Assuming that the set of possible evolution scenarios is finite and is known along with probabilities of realization of such scenarios, we derive necessary conditions for optimal non-anticipating strategies in terms of some non-standard maximum principle. The main feature of this maximum principle is a new extended adjoint system which is significantly different from the one in classical Pontryagin maximum principle. We demonstrate that these new optimality conditions can be used for a construction of optimal discontinuous feedback control. Robustness properties of this feedback with respect to small measurement errors of state vector and small perturbations of the dynamics are also studied.

16:50-17:10 ThR4B.3

Dynamical Input Reconstruction Problem for a Quasi-Linear Stochastic System, pp. 727-732

Rozenberg, Valerii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The problem of reconstructing unknown inputs in a quasi-linear stochastic system with diffusion depending on the phase state is investigated by means of the approach of the theory of dynamic inversion. The statement when the simultaneous reconstruction of disturbances in the deterministic and stochastic terms of the system is performed from the discrete information on a number of realizations of the stochastic process is considered. The problem is reduced to an inverse problem for ordinary differential equations describing the mathematical expectation and covariance matrix of the process. A finite-step software-oriented solving algorithm based on the method of auxiliary controlled models is proposed. The key result of the paper is an estimate for the convergence rate of the algorithm with respect to the number

of measurable realizations.

17:10-17:30	ThR4B.4

On the Problem of Package Guidance for Nonlinear Control System Via Fuzzy Approach, pp. 733-738

Surkov, Platon — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The problem of guaranteed closed-loop guidance at a given time is studied for a nonlinear dynamical control system. The initial state is unknown, but belongs to a given nite set of admissible initial states. The problem of package guidance is formulated for such system and a theorem of its solvability is proved by using the representation in the form of Takagi—Sugeno fuzzy model. An example illustrated the proposed technique by a specic nonlinear mechanical system is given.

ThR4V	Hotel VIP-Hall

Control of Partial Differential Equations II (Regular Session)

Chair: Izmest'ev, Igor' Vyacheslavovich — Chelyabinsk State Univ

Co-Chair: Pimenov, Vladimir — Ural Federal Univ

16:10-16:30	ThR4V.1

The Problem of Controlling the Process of Heating the Rod in the Presence of Disturbance and Uncertainty, pp. 739-742

Ukhobotov, Victor Ivanovich — Chelyabinsk State Univ
Izmest'ev, Igor' Vyacheslavovich — Chelyabinsk State Univ

The problem of controlling the process of heating the rod by changing the temperature at the left end of the rod is considered. The temperature at the right end of the rod is formed by a disturbance. The exact value of the heat density function is unknown, and only the boundaries of the range of its possible values are given. The goal of the control process is that at a fixed time the average value of the temperature of the rod belongs to the given interval. Necessary and sufficient conditions are found that the initial temperature of the rod must satisfy, so that the goal can be achieved for any admissible realizations of disturbance and uncertainty. The corresponding heating control of the left end of the rod is constructed.

16:30-16:50	ThR4V.2

Numerical Discretization for Fractional Differential Equations with Feedback Control, pp. 743-747

Hendy, Ahmed Said — Ural Federal Univ
Pimenov, Vladimir — Ural Federal Univ

In this paper, we introduce a numerical scheme for fractional differential equations with feedback control. Due to the possibility of dealing with a feedback control as a functional delay, we construct a numerical method based on Euler method accompanied with piecewise constant interpolation. The method is based on the idea of separating the current state and the prehistory function. The convergence of the method is stated and proved. Numerical experiments are given to clarify the good agreement between numerical and theoretical results.

16:50-17:10	ThR4V.3

Numerical Solution to the Dirichlet Control Problem on a Part of the Boundary for the Petrovsky System, pp. 748-753

Dryazhenkov, Andrey Alexandrovich — Faculty of Computational Mathematics and Cybernetics, Lomonosov MSU
Artemyeva, Liudmila — Lomonosov Moscow State Univ

For the Euler—Bernoulli plate equation the Dirichlet control problem is considered. To solve this problem numerically, a combination of classical regularization methods and a scheme of compact embedding of the spaces of optimal regularity into an auxiliary pair of spaces is used. Estimates of the uniform proximity of the exact and approximate operators in the new pair of spaces are obtained.

17:10-17:30	ThR4V.4

On the Solvability of Synthesis Problem for Optimal Point Control of Oscillatory Processes, pp. 754-758

Kerimbekov, Akylbek — Kyrgyz -Russian Slavic Univ
Tairova, Orozgul — Kyrgyz -Russian Slavic Univ

In this paper we consider the synthesis problem of optimal point control in the optimization of oscillatory processes in the case when the equation of the boundary value problem contains the Fredholm integral operator. The investigation is conducted according to the methodology of Professor A.I. Egorov developed by him on the basis of the Bellman scheme. Using the concepts of a generalized solution of the boundary value problem and the concept of the Fr'echet differential for the Bellman functional, we obtain the integro-differential Bellman—Egorov equation in partial derivatives. The structure of the solution of the Cauchy—Bellman—Egorov problem is found.

17:30-17:50	ThR4V.5

Volterra Functional-Operator Equations in the Theory of Optimal Control of Distributed Systems, pp. 759-764

Sumin, Vladimir — Nizhniy Novgorod State Univ

A survey of the results obtained in the theory of optimization of distributed systems by the method of Volterra functional-operator equations is given. Topics are considered: the conditions for preserving the global solvability of controllable initial-boundary value problems, optimality conditions, singular controlled systems in the sense of J.L. Lions, singular optimal controls, numerical optimization methods substantiation and others.

FrR1A	Hotel Hall A
Optimization Methods III (Regular Session)	
Chair: Filippova, Tatiana	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Co-Chair: Kazarinov, Lev	South Ural State Univ

09:30-09:50 FrR1A.1

A Method for Steam Boilers Load Optimization, pp. 765-769

Kazarinov, Lev — South Ural State Univ
Kolesnikova, Olga — South Ural State Univ
Tsypkaikina, Anastasia — South Ural State Univ

A method for energy efficiency improvement of power stations equipment for metallurgical complexes is proposed. The method is intended for load optimization of steam boilers equipment. Several optimization criteria are considered: (1) minimum of natural gas consumption by a group of steam boilers with the restrictions for steam generation, consumption of secondary energy resources and mode parameters; (2) maximum of efficiency factor; (3) combined criterion for minimum of natural gas consumption and maximum of efficiency factor. The optimization problem solution is based on steam boiler process models. The process models represent power characteristics of the equipment. The process models use optimal energy characteristics of equipment operational data as well as normal data. An example for load optimization of boiler equipment at the power station of a metallurgical complex was given to illustrate the proposed method. The results show that the optimization method allows to decrease the consumption of natural gas to 5%.

09:50-10:10 FrR1A.2

Differential Equations for Ellipsoidal Estimates of Reachable Sets for a Class of Control Systems with Nonlinearity and Uncertainty, pp. 770-775

Filippova, Tatiana — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The problem of estimating reachable sets of nonlinear dynamical control systems with combined nonlinearity of quadratic and bilinear types and with uncertainty in initial states and in system parameters is studied. We assume that the uncertainty is of set-membership kind when only the bounding sets for unknown parameters and functions are given. We find the ellipsoidal estimates of reachable sets using the special bilinear-quadratic structure of studied control system. The main result consists in deriving the related differential equations which describe the dynamics of the ellipsoidal estimates of reachable sets of the control system under study, related numerical simulation results are also given.

10:10-10:30 FrR1A.3

Array Patterns of Regulator Re-Optimization Algorithms Via Duality in Estimation and Control, pp. 776-781

Semushin, Innokentiy V. — Ulyanovsk State Univ
Tsyganova, Julia — Ulyanovsk State Univ
Tsyganov, Andrey — Ulyanovsk State Pedagogical Univ. Named after I.N. Ulyanov

In this paper, we construct new array patterns of regulator re-optimization algorithms using the duality relations between the two Riccati Difference Equations (RDE), that are at the heart of Linear Quadratic Gaussian Estimator (LQG-E) on the one part, and Linear Quadratic Regulator (LQR) on the other. By doing so, we advocate steps to integrate the best computational LQG-E solutions which have come into practice over the preceding decades, into the LQR re-design, in which a stepwise solution for the backward RDE has primary importance. Array-based algorithmic templates developed in this paper offer customization flexibility, together with the utmost brevity, to both users and application programmers, and ensure the independence of a specic program language.

10:30-10:50 FrR1A.4

The Sphere Packing Problem into Bounded Containers in Three-Dimension Non-Euclidean Space, pp. 782-787

Kazakov, Alexander — Matrosov Inst. for System Dynamics and Control Theory, SB RAS
Lempert, Anna — Matrosov Inst. for System Dynamics and Control Theory, SB RAS
Ta, Trung Thanh — Irkutsk National Res. Tech. Univ

This paper deals with the problem of optimal packing a given number of equal spheres into different closed sets. We consider the problem both in three-dimensional Euclidean and non-Euclidean spaces. The special algorithm based on optical-geometric approach is suggested and implemented. This approach is previously used only for packing circles in two-dimensional space. Numerical results are presented and discussed.

FrR1B	Hotel Hall B
Generalized Solutions of Hamilton—Jacobi Equations I (Regular Session)	
Chair: Turetsky, Vladimir	Ort Braude College of Engineering
Co-Chair: Obrosova, Nataliia	Dorodnicyn Computing Centre of FRC CSC RAS

09:30-09:50 FrR1B.1

Methodology for Assessing the Value of an Enterprise in the Depressed Sector of Economy Based on Solving of the Bellman Equation, pp. 788-792

Alimov, Damir — Lomonosov Moscow State Univ
Obrosova, Nataliia — Dorodnicyn Computing Centre of FRC CSC RAS
Shananin, Alexander — Moscow Inst. of Physics and Tech. Development

The new approach to assessing the real value of manufacturing companies in the manufacturing sector of the Russian economy using mathematical models is presented. Two variants of models corresponding to the period of Russian economic since 2008 are described. The main features of this period are unstable demand and the deficit of working capital. The models are formalized in the form of the Bellman equation for the valuation of the production company. The first version of the model is characterized by the presence of infrastructure constraints. The second version takes into account the impact of the debt burden on the company's operations. For the first case the explicit form of the solution of the Bellman equation was found and the system of algebraic equations connecting model variables with parameters observed by official statistics are constructed. We made numerical calculations according to the official data of company Sollers for 2013–2017. For the modification of the model conditions of the existence and the uniqueness of the solution of the Bellman equation are found and the optimal producers behavior for different economic conditions are described.

09:50-10:10 FrR1B.2

A Mean Field Game Approach for Multi-Lane Traffic Managemen, pp. 793-798

Festa, Adriano — INSA Rouen
Goettlich, Simone — Univ. of Mannheim

In this work, we discuss a Mean Field Game approach to traffic management on multi-lane roads. The control is related to the optimal choice to change lane to reach a desired configuration of the system. Such approach is particularly indicated to model self-driven vehicles with complete information on the state of the system. The mathematical

interest of the problem is that the system of partial differential equations obtained is not in the classic form, but it consists of some continuity equations (one for each lane) and a variational inequality, coming from the Hamilton—Jacobi theory of the hybrid control. We propose a consistent semi-Lagrangian scheme for the approximation of the system and we discuss how to improve its efficiency with the use of a policy iteration technique. We finally present a numerical test which shows the potential of our approach.

10:10-10:30	FrR1B.3

On the Value of Differential Game with Asymmetric Control Constraints, pp. 799-804

Turetsky, Vladimir — Ort Braude College of Engineering
Hayoun, Shmuel Yonatan — Technion - Israel Inst. of Tech
Shima, Tal — Technion - Israel Inst. of Tech
Tarasyev, Alexander M. — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

A differential game with asymmetric constraints on the players' controls and an asymmetric cost functional is considered. In this game hard geometric constraints are imposed on the maximizer, whereas the minimizer is soft-constrained by including the control effort term into the cost functional. The sufficient condition is derived, subject to which the program maximin is the game value. In the proof, it is shown that the program maximin is the generalized solution of the Hamilton—Jacobi—Bellman partial differential equation. Examples are presented.

10:30-10:50	FrR1B.4

On Approximation of Multivalued Solution for Hamilton—Jacobi Equation, pp. 805-809

Kolpakova, Ekaterina — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The paper deals with the Cauchy problem for Hamilton—Jacobi equation with discontinuous w.r.t. phase variable Hamiltonian. In this case we use the notion of M-solution proposed by Subbotin. We consider the sequence of auxiliary Cauchy problems for Hamilton—Jacobi equations with Lipschitz continuous w.r.t. phase variable Hamiltonians. We show that the sequence of distances between of graphs of solutions for auxiliary Cauchy problems and graph of M-solution tends to zero in metrics L^1.

FrR1V	Hotel VIP-Hall
Robust Control and Stabilization IV (Regular Session)	

Chair: Zaitsev, Vasilii — Udmurt State Univ

Co-Chair: Dmitriev, Mikhail — Federal Res. Center “Computer Science and Control” of Russian Acad. of Sciences (FRC CSC RAS)

09:30-09:50	FrR1V.1

Arbitrary Spectrum Assignment by Static Output Feedback for Linear Differential Equations with State Variable Delays, pp. 810-814

Zaitsev, Vasilii — Udmurt State Univ
Kim, Inna — Udmurt State Univ

For a linear time-invariant control system defined by a linear differential equation with several delays in the state variable, a spectrum assignment problem by linear static output feedback with delays is studied. Sufficient conditions are obtained for solvability of the arbitrary spectrum assignment problem.

09:50-10:10	FrR1V.2

Construction of Parametric Regulators for Nonlinear Control Systems Based on the Pade Approximations of the Matrix Riccati Equation Solution, pp. 815-820

Danik, Yulia — Federal Res. Center “Computer Science and Control” of RAS
Dmitriev, Mikhail — Federal Res. Center “Computer Science and Control” of RAS

An approach to the construction of state controllers for nonlinear control systems with a parameter represented in a pseudo-linear form based on the Padé approximations of the solution of a matrix algebraic Riccati equation with state-dependent coefficients is demonstrated. Two classes of problems are considered. The first class of problems represents the systems in which the small value of the parameter on the right-hand side of the system equations leads to a weakly controlled system, and in case of a large value of the same parameter we have a large gain control. The second class of problems is devoted to quasilinear regularly perturbed systems, where the parameter on the right-hand side can take arbitrary positive values.

10:10-10:30	FrR1V.3

LMI-Based Design of Output Robust Controller, pp. 821-825

Kakanov, Mikhail — ITMO Univ
Borisov, Oleg — ITMO Univ
Gromov, Vladislav — ITMO Univ
Pyrkin, Anton — ITMO Univ
Shavetov, Sergei — ITMO Univ
Somov, Sergey — ITMO Univ

This paper is devoted to the problem of output robust control for SISO systems with guaranteed settling time. To ensure specified convergence rate of system, toolkit of linear matrix inequalities (LMI) is used. Simulation result are presented in the paper.

10:30-10:50	FrR1V.4

Adaptive Robust Stabilization of an Aperiodic Transient Process Control Quality in Systems with Interval Parametric Uncertainty, pp. 826-831

Khozhaev, Ivan — National Res. Tomsk Pol. Univ

The paper is dedicated to a development of a controller synthesis method for system with uncertainty parameters. Developed method combines two approaches to control: an adaptive one and an interval one; and allows providing a desired quality of an aperiodic transient process despite interval parametric uncertainty of a system. Application example of a developed method is provided; synthesized system was examined via simulation modeling. Synthesis results, obtained with the help of developed method, were compared to results, obtained with previously developed methods.

FrR2A	Hotel Hall A
Optimization Methods IV (Regular Session)	

Chair: Lempert, Anna — Matrosov Inst. for System Dynamics and Control Theory, SB RAS

Co-Chair: Shorikov, Andrey — Ural Federal Univ. Named after the First President of Russia B.N. Yeltsin

11:20-11:40	FrR2A.1

On Some Nonlinear Control System Problems on a Finite Time Interval, pp. 832-837

Ushakov, Vladimir — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Matviychuk, Alexander — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Parshikov, Grigory — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Ukhobotov, Victor I. — Chelyabinsk State Univ

In this presentation we evaluate nonlinear control systems on a finite time interval. We also discuss application of the

invariance features and weak invariant sets in the procedures of constructing solutions for approach problems. These problems are closely connected with evaluation of reachability sets and integral funnels of control systems. We revise several problems of approaching and one general scheme of constructing solutions for these problems. Scheme consist of two stages: at the first stage we construct approximate reachability set of the approach problem; at the second stage in one way or another we construct control on a given time interval that solves the approach problem.

11:40-12:00	FrR2A.2

Algorithm for Solving of Two-Level Hierarchical Minimax Adaptive Control Problem in a Linear Discrete-Time Dynamical System, pp. 838-843

Shorikov, Andrey — Ural Federal Univ

In this paper we consider a discrete-time dynamical system consisting from two controllable objects. The dynamics of each object is described by the corresponding vector linear discrete-time recurrent relation. In this dynamical system there are two levels of control. The quality of process implementation at each level of the control system is estimated by the corresponding terminal linear functional. For the dynamical system under consideration, a mathematical formalization of a two-level hierarchical minimax adaptive control problem in the presence of perturbations, and an algorithm for its solving are proposed. The construction of this algorithm can be implemented as a finite sequence of solutions of a linear mathematical programming problems, and a finite discrete optimization problems.

12:00-12:20	FrR2A.3

Online Tuning of PID Controller Using Black Box Multi-Objective Optimization and Reinforcement Learning, pp. 844-849

Pandit, Ashwad — Cummins India Limited
Hingu, Bipin — Cummins India Limited

A PID Controller is the most widely used controller due to its ease and convenience of use. Manual tuning of a PID Controller is a time-consuming task. Hence, employing intelligent algorithms is necessary. The Cummins engine controller has a complex structure. To fine-tune it, a substantial amount of time is required. To reduce this time requirement, a black box approach was selected for online tuning. This would not only reduce the required time, but also reduce the efforts. Black box optimization would mean the engineers have to spend less time trying to understand the controller structure. With this aim in mind, a PID system simulation was set up in MATLAB. A function would randomize a system, resulting in a true black box to tune. This removed any bias the authors might have. The algorithm has shown promising results, with tuned controller gains in just over 20 iterations on average. This could then be extended to not only Cummins controllers, but other industrial controllers as well.

12:20-12:40	FrR2A.4

Multiple Covering of a Closed Set on a Plane with Non-Euclidean Metrics, pp. 850-854

Lempert, Anna — Matrosov Inst. for System Dynamics and Control Theory, SB RAS
Le, Quang Mung — Irkutsk National Res. Tech. Univ

The article is devoted to multiple circle covering problem for a bounded set in a two-dimensional metric space with a given amount of circles. Such statements arise in the construction of global navigation systems like GPS and Glonass. A similar problem appears in infrastructure logistics if there is a main servicing system and it is necessary to create a duplicate system to support service in the case of failure of one or more nodes. To solve this problem, we propose a computational algorithm based on a combination of the optical-geometric approach due to Fermat and Huygens principles and Voronoi diagram. A key feature of the algorithm is the ability to deal with non-Euclidean metrics. Numerical results and a comparison with known approaches are presented and discussed.

FrR2B	Hotel Hall B

Generalized Solutions of Hamilton—Jacobi Equations II
(Regular Session)

Chair: Subbotina, Nina — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Co-Chair: Shagalova, Lyubov — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

11:20-11:40	FrR2B.1

The Value Function in a Problem of Chemotherapy of a Malignant Tumor Growing According to the Gompertz Law, pp. 855-860

Novoselova, Natalia — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Subbotina, Nina — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

In this paper a construction of the value function is obtained in the problem of chemotherapy of a malignant tumor growing according to the Gompertz law, when a therapy function has two maxima. The aim of therapy is to minimize the number of tumor cells at the given final instance.

11:40-12:00	FrR2B.2

The Value Function of a Differential Game with Simple Motions and an Integro-Terminal Payoff Functional, pp. 861-865

Shagalova, Lyubov — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

An antagonistic positional differential game of two persons is considered. The dynamics of the system is described by a differential equation with simple motions, and the payoff functional is integro-terminal. For the case when the terminal function and the Hamiltonian are piecewise linear, and the dimension of the state space is two, a finite algorithm for the exact construction of the value function is proposed.

12:00-12:20	FrR2B.3

Bifurcation Points of the Generalized Solution of the Hamilton—Jacobi—Bellman Equation, pp. 866-870

Rodin, Aleksei — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Shagalova, Lyubov — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

Properties of a minimax piecewise smooth solution of the Hamilton—Jacobi—Bellman equation are considered in the article. We study necessary and sufficient conditions for finding bifurcation points. Such points are points of "nucleation" of the set where the solution is not differentiable.

12:20-12:40	FrR2B.4

Regularized Lagrange Principle and Pontryagin Maximum Principle in Optimal Control and Inverse Problems, pp. 871-876

Sumin, Mikhail — Nizhnii Novgorod State Univ

Regularized Lagrange principles in non-iterative and iterative forms for the “simplest” convex programming problem in a Hilbert space with operator constraint-equality are formulated. On their basis regularized Lagrange principle and Pontryagin maximum principle in iterative forms with stopping rules are derived in optimal control problem and in inverse problem for parabolic equation.

FrR2V	Hotel VIP-Hall
Numerical Methods for Optimization III (Regular Session)	

Chair: Trofimov, Sergey	Ural Federal Univ
Co-Chair: Matviychuk, Oxana G.	Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

11:20-11:40 FrR2V.1

Estimation Techniques for Bilinear Control Systems, pp. 877-882

Matviychuk, Oxana G. — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS

The problem of estimating reachable sets of impulsive control systems with uncertainties in initial states and in the matrix of the system is studied. We assume that the initial states to be unknown but belong to a given star-shaped symmetric nondegenerate polytope. The matrix included in the differential equations of the system dynamics is uncertain and only bounds on admissible values of this matrix coefficients are known. We present here the approach that allow to find ellipsoidal estimates of reachable sets which uses the special structure of the bilinear control system. The algorithm of constructing such ellipsoidal set-valued estimates and numerical simulation results are given.

11:40-12:00 FrR2V.2

Optimization of Complex Functions and the Algorithm for Exact Geometric Search for Complex Roots of a Polynomial, pp. 883-888

Trofimov, Sergey — Ural Federal Univ

The paper describes an application for visualization of four-dimensional graphs of a complex variable function. This application allowed us to construct an exact geometric algorithm for finding the real and complex roots of a polynomial on the same plane. A graph of an n-th order polynomial on the real plane allows us to define geometrically all the real roots. Number of real roots varies from 0 to n. The rest of the roots are complex and not determined by the graph. In the article, in addition to the graph of the basic polynomial, two auxiliary graphs are constructed, which allow us to represent all complex roots on the same real plane. Realization of this method is considered in detail for the solution of a cubic polynomial. In this case the method has exceptional features in comparison with polynomials of other degrees. We also propose an algorithm for constructing auxiliary functions for the general case of a polynomial of order n which have exact formulas for polynomials with order $n \leq 10$. The algorithm for the first time builds the exact hodograph of poles for the control systems with feedback. We generalize the concepts of stationary and extremal points to the case of a complex function. The absence of the possibility of comparing the complex values of the objective function is compensated by an analysis of the behavior of the stationary point under small perturbations of the polynomial by linear functions. Optimality criteria are proposed using complex trajectories of stationary points.

12:00-12:20 FrR2V.3

Fixed Types of Motion in Aircraft Trajectory Recovering, pp. 889-894

Ivanov, Alexey G. — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Bedin, Dmitrii — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Fedotov, Andrey — Krasovskii Inst. of Mathematics and Mechanics, UB of RAS
Ganebnyi, Sergei — New Information Tech. in Aviation, LLC

We describe an algorithm for recovering a trajectory of an aircraft that is based on the construction of a bundle of approximating trajectories. Each of them is a possible version of the real aircraft motion. The specific feature of the algorithm is the approximation of measurements by means of a fixed set of motion patterns. A procedure of detecting the motion type determines the most probable motion pattern, and then the weight of the corresponding approximating trajectory in the final estimate of the aircraft current position increases. Such a design improves the accuracy of the coordinate determination at the stages of steady motion. The results of application of the algorithm to some model data are presented.

12:20-12:40 FrR2V.4

On Nonconvex Optimization Problems with D.C. Equality and Inequality Constraints, pp. 895-900

Strekalovsky, Alexander — Matrosov Inst. for System Dynamics and Control Theory, SB RAS

The paper addresses the nonconvex nonsmooth optimization problem with the cost function and equality and inequality constraints given by d.c. functions. The original problem is reduced to a problem without constraints with the help of the exact penalization theory. After that, the penalized problem is represented as a d.c. minimization problem without constraints, for which the new mathematical tools under the form of global optimality conditions (GOCs) are developed. The GOCs reduce the nonconvex problem in question to a family of convex (linearized with respect to the basic nonconvexities) problems. In addition, the GOCs are related to some nonsmooth form of the KKT-theorem for the original problem. On the base of the developed theory we propose new numerical methods for local and global search.

AUTHOR INDEX

KEYWORDS INDEX

GENERAL INFORMATION

Location

Yekaterinburg is the fourth-largest city in Russia and the administrative center of Sverdlovsk Oblast, located on the border of Europe and Asia. It has a population of about 1.4 mln.

Yekaterinburg was founded in 1723, named after Russian emperor Peter the Great's wife, Yekaterina (Catherine I). It served as the mining capital of the Russian Empire as well as a strategic connection between Europe and Asia. During the 18th century, the city became known as Russia's iron making center, and it is now a modern city with world-class infrastructure that includes an efficient metro system and an excellent airport. The city is also one of Russia's most well-known centers for the arts, science, education and sports. Yekaterinburg has the third largest number of diplomatic missions in the country (after Moscow and St.Petersburg).

Yekaterinburg is one of the Host Cities for 2018 FIFA World Cup Russia™.

Koltsovo International Airport is one of the largest airports in the country. It was awarded by the National Aviation Infrastructure Show as the best passenger international airport with passenger traffic below 7 mln. and as the best cargo airport.

Venue

The Workshop will take place at ***"Ural" Cultural Center*** (3 Studencheskaya Street, Yekaterinburg), at ***Krasovskii Institute of Mathematics and Mechanics*** (16 S.Kovalevskaya Street, Yekaterinburg), and at three Conference Halls (Hall "A", Hall "B", VIP-Hall) of ***Oktyabrskaya Hotel*** (17 S.Kovalevskaya Street, Yekaterinburg).

Registration

On-the-spot registration of the participants will begin in advance, on Sunday, October 14, 2018, afternoon, at the Oktyabrskaya Hotel (17 S.Kovalevskaya Street). On Monday, October 15, the registration will be continued from 9:00 at the "Ural" Cultural Center (3 Studencheskaya Street) and from 14:00 at the Oktyabrskaya Hotel.

Social and Cultural Program

The program of CAO 2018 will include the following social events:

- ***Welcome Reception*** will take place at the Restaurant of Oktyabrskaya Hotel on Monday, October 15, evening.
- *The first* ***City Tour*** will be organized on Tuesday, October 16, after lunch, in parallel with the regular sessions TuR2 and TuR3.
- ***Conference Dinner*** will take place at the Restaurant of Oktyabrskaya Hotel on Wednesday, October 17, evening.
- *The second* ***City Tour*** will be organized on Thursday, October 18, evening.