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METAHEURISTIC ALGORITHMS FOR MULTI-AGENT ROUTING PROBLEMS

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Abstract. The problems of constructing routes in complex networks by many sales agents are considered. Formalization leads to problems of pseudo-Boolean discrete optimization with restrictions that take into account the specifics of route construction. The sparsity of the constraint matrix makes it possible to apply decomposition approaches and network clustering. The development of approximate algorithms for selecting routes in complex networks involves taking into account the properties of the network structure, its complexity, the presence of restrictions, regulations, reachability conditions, and the number of sales agents. It is shown that the solution of routing problems can be based on the application of a multi-agent approach in combination with clustering (decomposition) of the original problem and metaheuristics. Multi-agent systems with swarm intelligence are used to solve complex discrete optimization problems that cannot be effectively solved by classical algorithms. The agent model for a complex network of problems like many traveling salesmen becomes an intellectualized system that defines heuristic algorithms for finding the optimal solution by reactive agents (that follow the rules laid down in them). The compositions of the algorithms described in detail, which have proven themselves well in computational experiments, are used; those are modification of the genetic algorithm, ant colony optimization, artificial bee colony algorithm, simulated annealing. A generalized algorithm is proposed and implemented, in which a simpler network (a flyover network) is matched to the source network. In this case, a numerical experiment was performed for the problem of routing on a GIS map for urban infrastructure. Clustering algorithms are implemented, in which the initially traversed routes are refined using 2-opt algorithms, simulated annealing, and other metaheuristics. A comparison of the algorithms used and an illustration of their operation are given.

Keywords: metaheuristic algorithms, multi-agent optimization problems, discrete optimization, pseudo-Boolean problems.

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ABSOLUTE STABILITY OF SYSTEMS WITH CONTROLLERS THAT PROVIDE GIVEN OSCILLATION INDEX

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Abstract. Linear multivariable tracking systems are considered, which controllers provide given or achievable separate oscillation indices, in particular, they minimize H_∞ norm of the system closed loop transfer matrix that connects a vector of references with a vector of controlled variables. An aggregate of the separate oscillation indices for the *i*th closed loop connecting the *i*th reference signal with the *i*th controlled variable is considered as a performance index. Such an approach is of great practical interest for engineers that design automatic systems. Based on the multivariable circle criterion of absolute stability, it is proved that the closed loop system is stable in whole if non-stationary sector nonlinearities are entered in the control loop at the plant output. Relation between the oscillation index obtained during controller synthesis and the size of sector which bounds feasible nonlinearities characteristics is found. This result of the paper is sufficient. Relation between the separate oscillation index and the Nyquist plot of system with the break point at the corresponding plant output is proved.

Keywords: linear multivariable systems, oscillation index, Nyquist plot, sector non-stationary nonlinearities, absolute stability.

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A STUDY OF CONTEST SUCCESS FUNCTION FOR BATTLES (COMBATS, OPERATIONS)

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Abstract. A statistical study of contest success functions for battles was performed, based on the model of G. Tullock, which establishes the dependence of battle (combat, operation) victory probability on the ratio of combat potentials of the sides. The combat potential is determined by the number of combat units of the sides and takes into account their moral and technological characteristics. The scale parameter (according to G. Tullock, the decisiveness parameter) is estimated by using the examples of battles that took part in the 19th and early 20th century, the results of strategic operations of the Great Patriotic War of 1941–1945, the data on clashes between border guards and bandit groups, and also on the base of international statistical data on acts of piracy and armed robbery at sea. For counter-terrorism and special operations, its value is small; at the tactical level, it equals one; at the operational level its approximate value is 2–4. The obtained statistical results do not contradict the military science and art ideas of planning and conduct of hostilities. Using the contest success function for battle (combat, operation) is advisable at the stage of preparation for the battle to substantiate the required forces and means for completing the tasks.

Keywords: contest success function, Tullock model, parameter estimation, scale parameter, battle, combat, operation.

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MANAGING ECONOMIC EFFICIENCY OF PRODUCTION SYSTEMS IN A FLUENT STREAM OF NEW PROJECTS

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Abstract. In conditions when new innovative products appear constantly, there is a need for implementing more effective planning and production systems activity management by means of formalization level increase while describing the processes related to formation of production portfolio of a production system. The aim of the article is to solve the scheduling problem and to define requirements for the projects and their flow, which allow the production system to function effectively in conditions of environment uncertainty. The methods of simulation modeling, system analysis, statistical processing of the received results are applied for the purpose of their generalization and machine learning for search and classification of projects and routes of the possible development of production systems. As a result of the research, the model has been obtained, that allows determining empirically the projects and trajectories of the production systems development for the given characteristics of the projects, which will lead to the effective functioning of the systems on the basis of using historical data about the implemented projects to take into account the specifics of the considered system. A number of statements have been formulated that allow us to specify the problem considered in the article and to designate the described approach applicability limits. Knowledge received about the stream of projects and the projects themselves will allow formulating requirements for projects and activities connected with the search and development of new products. The greatest value of the described research lies in the fact that the obtained results show a decrease in the significance of expert assessments when choosing projects and setting targets, as well as a possibility of transition to formal methods, which leads to increasing the objectivity of the obtained assessments.

Keywords: production system, innovation project, project flow, model, simulation, scheduling, economic efficiency, Poisson point process.

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DECENTRALIZED AUTONOMIC SYNCHRONIZATION OF INTERACTION PROCESSES OF MOBILE OBJECTS

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Abstract. A fully decentralized autonomous method of synchronization of objects interaction in distributed systems of mobile objects (for example, robots) is proposed. It synchronizes the simultaneous transmission of signals from a group of signal-source objects to a group of signal receivers, accelerates group data transmission and execution of distributed computations directly in the network facilities of the system. Decentralization eliminates the presence of a center that manages the synchronization processes within the group of objects. Autonomy allows performing synchronization without interaction with external controlling technical means. The objects of the group exchange non-directional signals via wireless optical or radio communication channels. Two interacting synchronization processes are used. The main purpose of the first process of the group sync process is to sequence the actions of a group of asynchronous objects and provide input data for the second sync correction process. The second process accelerates the group data transmission and the execution of distributed computations directly in the network facilities of the system due to faster and more accurate account for changes in the location of moving objects than in the first process. The first process can be used independently of the second process to determine the location, speed, and acceleration of moving objects relative to each other and to external active or passive objects. On the whole, the proposed synchronization without the influence of a dedicated control center translates a group of mobile objects from a random state into a synchronized mobile system.

Keywords: mobile objects group, synchronization, autonomy, decentralization, system self-organization, synchronous distributed network computing.

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A DIGITAL PLATFORM FOR IMPLEMENTING DISTRIBUTED ENERGY RESOURCES MANAGEMENT SYSTEMS

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Abstract. The problems of intelligent control of modern electric power systems with distributed energy resources (DER) are considered. Such systems contain various energy consuming equipment (including those with demand-side management capabilities), on-site generation equipment, and energy storage devices. An approach to develop and execute DER management systems on the basis of a digital platform is advocated. A typical control process based on the platform is described, aimed at improving the operation efficiency of physical or virtual DER groups by means of optimal planning and simulation on digital twins. Scenarios of employing the platform in DER operational management are listed. The mathematical basis of the platform is presented, including automatic modeling and analysis of electrical modes on digital twins, optimization planning and control algorithms, forecasting consumption/generation profiles and technical and economic factors.

Keywords: distributed energy resources, digital platform, digital twin, smart contract, optimal equipment operation planning.

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OPTIMAL CONTROL OF THERMAL EXPOSURE SOURCE IN THE PROCESSES OF VAPOR PHASE DEPOSITION

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Abstract. We consider a mathematical model that describes the process of heating a silica tube by a movable heat source. The model is represented in the form of a one-dimensional heat conduction equation. Based on this model, we solve the problem of optimal stabilizing control with distributed control and distributed observation for the linearized problem. The value of the gas mixture flow rate, which determines the power of the heat source, was selected as a control influence. The aim of the control was to minimize possible temperature deviations from the programmed regimes of the silica pipes alloying. We obtained necessary optimality conditions in the form of an optimization system consisting of two partial differential equations. A law for finding the optimal control function, which explicitly depends on the solution of the mentioned system of equations, was obtained as well. Ultimately, we carried out the numerical solution of the optimization system and obtained quantitative results for the control function. We also calculated and analyzed the temperature distributions in various control modes.

Keywords: optimal control, MCVD process, distributed system, optimization system.