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ABSTRACTS

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National Research University Higher School of Economics, Nizhny Novgorod

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В сборнике опубликованы материалы участников конференции, посвященные исследованиям в области математического программирования, дискретной оптимизации, теории игр, оптимального управления, оптимизации в машинном обучении и анализе данных, приложений в исследовании операций.

Материалы конференции изданы в авторской редакции.

CONTENT

Blockchain-Enhanced Selective Newsvendor Optimization

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Abstract. Blockchain Technology (BCT) is currently getting lot of attention from leading firms and researchers worldwide. It has been embraced as a disruptive technology, though it is still in a nascent stage. The adoption of BCT has been reported to reduce overall unit cost and improve demand of the product while simultaneously adoption costs. Previous study has looked at how BCT is used in traditional single-market newsvendor settings. However, in parallel there several research on selective newsvendor problem (SNVP), which focuses on optimizing the scenario, where there are multiple markets and the firm needs to decide which market to serve and how much to order needs to be placed. This study links these two areas by creating a integrated selective newsvendor model in which a firm choose how much BCT to adopt, which markets to service and how much quantity to order over a single period. The study provides and explores the integrated blockchain adoption enabled SNVP. In order to solve the model, the study used one-dimensional grid search combined with the DERU (Demand-to-risk adjusted index) approach. This means for a fixed adoption level, the best market set can be found by looking at ordered DERU candidates instead of listing all subsets. The complete model is solved by integrating this structure with a one-dimensional search across the adoption level α in the range [0,1]. Furthermore, numerical simulations demonstrated the model's dynamics and demonstrate how adoption costs, demand influences, and other parameters collectively determine optimal adoption, market selection, and optimal order quantity.

2D Hadamard Gradient Filtering with Scalar-Gradient Fusion for Robust Optimization

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Abstract. Gradient-based optimization methods often fail in real-world environments characterized by non-smooth landscapes and severe, heavy-tailed, or correlated noise. To address this, we introduce the Hadamard-Transformed Adam (HT-Adam), a structure-aware enhancement for gradient-based optimization on multimodal 2D landscapes. Instead of relying solely on local finite differences, HT-Adam samples the objective function on a small local grid around the current iterate and applies the 2D Fast Walsh-Hadamard Transform (FWHT). By applying an adaptive, time-varying low-pass mask in the sequency domain, the method effectively suppresses high-frequency noise while preserving the global topological structure of the landscape. The denoised gradient is then estimated via least-squares plane fitting and fused into the Adam optimizer’s moment estimates. Extensive experiments across various challenging continuous and non-smooth test surfaces under diverse noise models (including Cauchy, heteroscedastic, and correlated AR1 noise) demonstrate that HT-Adam achieves significantly faster convergence and higher global minima success rates compared to conventional optimizers and alternative spatial filtering techniques (Gaussian, Median). The method provides a robust "noise-canceling lens" for gradient updates, bridging signal processing and optimization with minimal computational overhead.

Systemic effects of prosumer coalition on an integrated energy system[1]

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Abstract. The rapid development of renewable energy technologies and the global drive for decarbonization are driving the transformation of energy systems. This, in turn, is leading to the widespread adoption of distributed energy sources and the emergence of prosumers, whose advantages include flexibility and maneuverability [1]. Prosumers can unite in coalitions, providing localized management and coordination of energy supply in decentralized areas. This requires aligning the interests of various actors and ensuring effective coordination within coalitions, which is crucial for improving the efficiency of the energy supply process and ensuring its sustainability. Organizing the cooperative functioning of prosumers is complex and requires innovative approaches. In this paper, we use agent-based technologies and cooperative game theory to study the interactions of active consumers in coalitions and determine the effects fron coalition on all participants in the energy system, including those not participating in the cooperation. We formulate a mathematical formulation of the problem [2], incorporating two distinct approaches to evaluate the impact of players joining coalitions – one that considers systemic coalition effects and another that does not. Applying our developed multi-agent energy system model, we perform calculations for 27 different coalition configurations involving five prosumers, then utilize four decision-making concepts – Prenucleolus, Modiclus, Shapley vector, and Tau vector [3] – to compute the distribution of joint gains among these prosumers in both described scenarios. The results clearly illustrate the critical importance of taking into account the systemic effects arising from prosumers joining coalitions. This consideration leads to significant reductions in overall energy supply costs in general.

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Register Allocation in Basic Blocks Using Memory-Aware and Randomized Linear Scan

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Abstract. We consider the register allocation problem within a single basic block. A formal model is introduced in which the placement of live intervals is constrained by the number of available registers, and the objective function minimizes the total memory access cost, measured as the number of spill/fill operations.

Linear Scan is used as the baseline allocation algorithm. Classical eviction heuristics, such as Longest-First and Furthest-First, rely solely on structural properties of live intervals and do not account for the current memory state of a variable. We propose a unified Memory-Aware modification of the cost function that incorporates whether evicting an interval requires an additional memory write. This adjustment increases the priority of "clean" intervals while only moderately perturbing the candidate ordering induced by the underlying heuristic.

In addition, we introduce a window-based randomized scheme: the program is partitioned into fixed-size windows, and within each window multiple randomized runs of Linear Scan are performed, where the interval to evict is selected probabilistically according to the cost function values. After all runs are completed, the best solution is fixed and used as the initial state for the next window. This mechanism can be interpreted as a local stochastic search in the space of feasible allocations. Experimental results demonstrate a reduction in the number of spill/fill operations compared to the baseline heuristics and provide an analysis of the impact of the Memory-Aware parameters and the randomized scheme on allocation quality; the latter achieves improvements at the cost of increased computational overhead.

Logistics Network Optimization: Algorithms and Industrial Implementation

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Abstract. This work is dedicated to research, development and imple mentation of a parcel delivery optimization solution for large logistics company. The problem can be briefly formulated as follows: how to deliver millions of parcels in the network with thousands of post-offices with minimal cost under limited resources and specific business requirements? The problem statement with some business requirements, solving approaches and results was presented and discussed on MOTOR 2025 con ference. But a lot has changed over the past year. New business requirements were added to the model. Solving time decreased 15 times with an improvement of undelivered amount from 6% to 1,4%. Delivery cost and amount delivered in time were also improved a lot.
In this presentation, we discuss how to build a flexible solution for a largescale problem using the synergy of MIP, greedy heuristic, various neighborhood search, constraint propagation, self-implemented graph algorithms, and specific data structures. In addition, we want to share experience of business implementation in a large company with many actors and steak-holders.

Matheuristics for the Two-dimensional Irregular Knapsack Problem

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Abstract. We consider the irregular knapsack packing problem, which consists in placing a given finite set of irregular polygons into a bounded container with the objective of maximizing the utilized area of the knapsack. This problem belongs to the class of NP-hard combinatorial optimization problems and therefore requires the use of heuristic and approximate solution techniques.
We propose a matheuristic approach that combines a greedy construction heuristic with mathematical programming. Both components rely on a semi-discrete representation of the container domain. In the first phase, a greedy algorithm sequentially constructs a feasible packing by selecting item positions from a predefined set of admissible placement points, ensuring non-overlap and containment constraints. This semi-discrete strategy allows efficient feasibility checks while preserving sufficient flexibility of placement.
The initial solution obtained by the greedy phase is then improved by solving a mixed-integer linear programming (MILP) model that refines the placement of selected items while preserving feasibility. The mathematical model employed in the improvement step is based on a revised semi-discrete formulation derived from the approach proposed in [1]. Computational experiments are performed to evaluate the proposed method on benchmark instances of the irregular packing problem and to demonstrate its practical applicability and effectiveness.

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Improvements in the branch, bound and cut algorithm for the competitive facility location problem

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Abstract. The key element of an implicit enumeration algorithm for computing optimal solutions in bilevel competitive location models is a bounding procedure that calculates upper bounds for the objective function across subsets of solutions. In bilevel programming, such procedures are based on the so-called high-point relaxation of the original model. This relaxation is obtained by loosening the optimality constraint for the lower-level variables. However, in the context of competitive location models, these relaxations are often weak. To address this, additional constraints are introduced to strengthen them, thereby eliminating infeasible bilevel solutions from the relaxation. For the competitive facility location problem and related models, so-called c-cuts and f-cuts are employed [1]. The efficiency of a cut is determined by the number of solutions it eliminates from the relaxation.

The primary contribution of this study is the introduction of modified c-cuts and f-cuts, which activate more frequently than their original counterparts. Procedures for generating these modified cuts are also presented. Numerical experiments demonstrate a notable reduction in the number of explored nodes in the enumeration tree when the modified c-cuts and f-cuts are utilized.

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Heuristic Search for a Parameterized Similarity Measure of Cluster Partitions in a Complete Weighted Graph

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Abstract. This paper considers the problem of comparing a cluster partition of a set of objects with a given reference partition based on a parameterized similarity measure. A model is proposed in which objects are represented as vertices of a complete weighted graph, where edge weights are determined by a parameter vector that defines the sensitivity of the proximity measure with respect to individual features. For a fixed parameter vector, graph clustering is performed using standard methods such as k-means and spectral clustering. The resulting partition is compared to the reference partition by solving an optimal assignment problem. As a quality function, a discrepancy measure is used, based on the total weight of edges belonging to the symmetric difference of the sets of intra-cluster edges in the compared partitions. Parameter tuning is formulated as an outer minimization problem with respect to this discrepancy measure. Local heuristic search procedures are employed to find a solution. The iterative process includes varying the components of the parameter vector, re-clustering the graph, and evaluating the discrepancy until stable agreement is achieved. As a result, an interpretable parameter vector of the similarity measure is obtained, which can be used both for analyzing the structure of the data and for assigning new objects to the formed clusters. A computational experiment on medical data is also conducted to assess the stability and practical performance of the proposed approach.

Dixit-Stiglitz-Krugman Model: Comparative Statics of Equilibrium w.r.t. Investments in R&D

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Abstract. We study Trade Model under Monopolistic Competition of Producers [1], [2]. The mathematical apparatus uses the ideas of [3], [4]. The utility function is assumed to be additively separable. Transport costs are assumed to be of the iceberg type. The marginal costs are the decreasing functions w.r.t. fixed costs (investments in R&D). The specific form of the sub-utility function and marginal cost function is assumed to be unknown. Therefore, it is impossible to calculate the market equilibrium in closed form. Typically, local comparative statistics are studied w.r.t. some parameters: by market size (in the case of a closed economy) or by transportation costs (in the case of an open economy). We, however, conduct local comparative statistics w.r.t. R&D investment.

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Robust approach for savings counting in stochastic games

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Abstract. We consider a class of cooperative stochastic games with random duration and address the problem of cooperation sustainability using an axiomatic approach. In this approach, we define a set of desirable properties and then construct a payment scheme satisfying them – a set of functions that redistribute the players' payoffs. In existing schemes for stochastic games, some scenarios are not feasible due to insufficient savings to cover deficits at some stages. In our work we apply the robust approach from stochastic optimization theory to define players' savings so that any possible scenario can be realised and the scheme holds no savings at the end of the game. In this way, we ensure feasibility of all scenarios and guarantee sustainability of cooperation.

A continuous optimization framework for linear error-correcting codes

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Abstract. Linear error-correcting codes, especially low-density parity-check (LDPC) codes, are ubiquitous in modern communication systems. The maximum like- lihood decoding of an LDPC code is an NP-complete problem. Despite that, decoding algorithms are subject to ongoing research, with an important limitation such as using reduced computational resources.

One of effective approaches for decoding are the so called *gradient-descent bit-flipping (GDBF) algorithms* [1, 2]. Despite having strong connection with continuous optimization, such algorithms operate on a discrete set of variables $x_j \in \{-1, +1\}$, subject to parity check constraints:

$$p_i(x) = \prod_{j \in N(i)} x_j = +1,$$

where $N(i), i \in [1, m]$ are sets of indices. The constraints verify data integrity by ensuring the sum of specific bits $b_j = (x_j + 1)/2 \in \{0, 1\}$ in a codeword is even.

Finding equivalence between discrete and continuous problems is a recog- nized, powerful technique in mathematics and optimization (see e.g. [3]). Fol- lowing this tradition, we claim that it is possible to translate formulation of the problem into a pure continuous form, thus enabling application of various con- tinuous optimization methods. In the same time, we restrain ourselves from a statement that it is possible to find more effective algorithms for decoding using such formulation. This, at the present moment, is unknown.

Our first observation is that monomials $p_i(x), i \in [1, m]$ have the property of being R-functions [4, 5] and their signs are determined solely by the signs of their arguments. Therefore, we can easily replace our discrete variables with the components of a vector $x \in R^n$ and instead of equality $p_i(x) = +1$ consider inequality: $p_i(x) > 0$. Irrespective of the magnitude of x_j, we are now interested only in its sign.

In our second observation, we note that $p_i(x)$ (now with continuous arguments) are homogeneous polynomials: $p_i(\lambda x) = \lambda^k p_i(x), k > 0$. Since the sign of $p_i(\lambda x)$ does not change for any $\lambda > 0$, it leads us to optimization over the unit sphere or simplex boundary (or over the boundary of any convex body containing the origin, if it makes sense). Considering unit sphere [6, 7], one can recast the original problem as an optimization problem on a smooth manifold [8, 9].

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Coalition graphs of connected domination partitions in subcubic graphs

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Abstract. A graph is subcubic if it is connected and its maximum vertex degree does not exceed 3. Two disjoint vertex subsets of a graph G form a connected coalition in G if neither of them is a connected dominating set but their union is a connected dominating set. A connected coalition partition of G is a partition $\pi(G)$ of its vertices, such that each set of $\pi(G)$ is either a connected dominating set consisting of a single vertex or forms a coalition with some set of $\pi(G)$. The formation of connected coalitions is described by a coalition graph whose vertices correspond to the sets of $\pi(G)$, and two vertices are adjacent if and only if the corresponding sets form a coalition in G. We characterize all coalition graphs of subcubic graphs. Namely, subcubic graphs de ne the following coalition graphs: the infinite set of stars S_k for $k \geq 2$ and the finite set of 22 graphs of order at most 6.

Threshold stability analysis for competitive pricing

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Abstract. We investigate the threshold stability of the three-level pricing problem described in [2]. This pricing problem can be described as a leader-follower-clients Stackelberg game, in which the leader and follower sequentially set price for a homogeneous product. This type of pricing is called uniform. Each client purchases the product from the facility where purchasing and transportation costs are minimal and within their budget. The goal of the leader or follower is to maximize their own revenue. In practice, client budgets are not always known precisely or may change over time. To examine this uncertainty, we use the concept of the thresh-old stability radius [1], which corresponds to the maximum budget deviation for which there exists a feasible solution of the original problem that satisfies the threshold constraint on the objective function value. The threshold stability problem itself is formulated as maximizing the threshold stability radius and finding a corresponding solution.
We consider several formulations of the threshold stability problem for three-level pricing and prove their polynomial solvability.

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Investigation of the threshold stability of the p-median problem with customer preferences in norms L_1 and L_∞

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Abstract. This paper investigates the threshold stabilityof the p-median problem with customer preferences. Two formulations are considered in which the uncertainty is specified by a vector of parameters and estimated in the L_1 and L_∞ norms.

Using projections of these formulations into the space of variables that define the location of facilities, exact formulas for the threshold stability radius were obtained. Based on these results, it is shown that the uncertainty region in each of the formulations is the set of feasible solutions of some linear programming problem. In the formulation with the L_1 norm, the convex hull of non-degenerate basic feasible solutions forms a facet consisting of all perturbations corresponding to the threshold stability radius. In the case of the problem with the L_∞ norm, only non-degenerate basic feasible solutions have a norm equal to the threshold stability radius. For all other solutions, the norm is strictly smaller, including the interior of the convex hull of non-degenerate basic feasible solutions.

The results obtained also imply that the problem of finding the threshold stability radius in any of the considered norms is computationally intractable if $P \neq NP$.

To solve the problems, approximate algorithms based on the VND heuristic have been developed. The algorithms differ in the characteristics of the neighborhoods used. The results of numerical experiments demonstrate the effectiveness of the approximate algorithms developed, both in terms of computational complexity and the quality of the approximate solutions.

Genetic Algorithm for a Temporal Bin Packing Problem with Placement Constraints

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Abstract. We consider a temporal bin packing problem from cloud computing, where bins are NUMA servers grouped into racks and items are virtual machines (VMs). Unlike the classic problem, we have a sequence of VM placement requests and need to pack as many of them as possible continuously (i.e., processing requests one by one without skipping any). The number of racks and servers is fixed in advance. Additional placement constraints require that VMs from conflicting subgroups of the same placement group cannot share a rack to ensure reliability.

We propose a genetic algorithm for this problem and test it on an open dataset, comparing it with First Fit, Best Fit, and Random Fit heuristics. The results show that our genetic algorithm significantly outperforms these heuristics in the number of requests placed, while remaining fast enough for practical use.

Quantum Crossovers for the Asymmetric Traveling Salesman Problem

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Abstract. In the case of adjacency-based representation of solutions to the Asymmetric Traveling Salesman Problem (ATSP), given two feasible parent tours A_1 *and* A_2 on a complete digraph $G = (V, A)$ with arc costs $c_{ij} \geq 0$, the *Optimal Recombination Problem (ORP)* seeks a shortest Hamiltonian circuit that (i) uses every arc belonging to both parents and (ii) uses only arcs present in at least one parent. This ORP [1] may be transformed into the TSP on a digraph $G'' = (V'', A'')$, where every vertex has in-degree and out-degree at most 3 and $|V''| \leq 2n$. To enumerate all feasible tours we consider the undirected graph $\bar{G} = (V'', \bar{E})$, where each symmetric arc pair in A'' becomes an edge, and forced arcs become the forced edge set $\bar{F}$. We replace the enumeration with a modified quantum algorithm [2], solving TSP on qubic graphs via a quantum walk with a bounded failure probability. Applied to $\bar{G}$, the algorithm finds a shortest admissible tour with any constant failure probability $\Delta \in (0, 1)$ in $O^*(1.233^n \log(L) \log\log(L))$ time, where L is the maximum cost, achieving a quantum speedup over previous bound $O(1.42^n)$.

In the case of position-based representation a tours is encoded as a sequence of city numbers $\pi = (\pi_1, \ldots, \pi_n)$. Given two parent tour π^1 and π^2, the ORP seeks a shortest tour π^* such that $\pi_i^* \in X^i$ for all i = 1, . . . , n, where $X^i = \{\pi_i^1, \pi_i^2\}$ if $\pi_i^1 \neq \pi_i^2$ and $X^i = \{\pi_i^1\}$ otherwise. This is exactly an instance of the *2-TSP with Vertex Requisitions* (2-TSPVR) [3]: find a bijection f^* from positions {1, . . . , n} to cities, with $f(i) \in X^i$, minimising $\sum_{i=1}^{n-1} c_{f(i),f(i+1)} + c_{f(n),f(1)}$.

As in [3], we build a *Quadratic Unconstrained Binary Optimization* model (QUBO) with $q \leq \lfloor n/2 \rfloor$ binary variables, and note that almost all feasible instances satisfy q = O(ln n). The QUBO is directly solvable by quantum annealers, providing a quantum crossover operator for position-based ORP for the ATSP.

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Fejér-type algorithm for finding a solution to a system of linear algebraic equations with two-sided constraints

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Abstract. The work is in line with the research of Fejér-type iterative algorithms, the foundations of which were laid and developed in the works of I.I. Eremin, V.V. Vasin, L.D. Popov, E.A. Berdnikova, I.M. Sokolinskaya, L.B. Sokolinsky, E.A.Nurminski.

The problem of calculating the solution of a system of linear algebraic equations (SLAE) with additional two-sided constraints on variables using a fast iterative algorithm of the Fejér-type is considered.

A description of the algorithm, its theoretical justification and the results of computational experiments are presented.

The footing of the algorithm is a fast iterative mapping of the Fejér-type for SLAEs with the condition of non-negative variables, previously discussed at the MOTOR-2025 conference, some other conferences and published in the work "An Accelerated Fejér-Type Process for Finding a Non-Negative Solution to a System of Linear Algebraic Equations. Trudy Instituta Matematiki i Mekhaniki UrO RAN, 2025, Vol. 31, № 3, pp. 121–137" (in Russian). English-language publication in the journal "Proceedings of the Steklov Institute of Mathematics, 2025, Vol. 331, Suppl.1"is being prepared for printing.

The drone placement problem for optimal coverage of the barrier is polynomially solvable in the rectilinear metric

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Abstract. A line segment, a barrier on a plane, is considered. Its monitoring (coverage) is performed by identical mobile sensors (drones) with a limited trajectory length. Each drone starts from its depot at a certain point on the barrier, moves along the barrier, and returns to its depot, having traveled a path of limited length. The part of the barrier along which the drone moved is covered by this drone. The barrier is covered if each of its points is covered by at least one drone. It is necessary to determine the number of drones in each depot and find the trajectory of each drone such that the entire barrier is covered and the total length of the drones' paths (trajectories) is minimal. A dynamic programming algorithm is known for solving this problem with Euclidean distance; it constructs an optimal solution with pseudo-polynomial complexity. Now we propose a polynomial algorithm to solve the problem in a rectilinear metric (L1), which constructs an optimal solution with quadratic complexity in the number of depots.

School Timetabling with Metagroups and Individual Plans

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Abstract. The school timetabling problem is a well-known NP-hard combinatorial optimization problem. It involves assigning lessons to a limited set of time slots while satisfying soft and hard constraints. In this research, we consider a formulation driven by the specific requirements of Moscow schools. The model operates with students following individual curricula, dynamically merged into study groups.

While classical formulations typically include basic hard constraints such as no overlaps for groups, teachers, and rooms, as well as fixed teacher-course-group assignments [1,2], our problem incorporates additional hard constraints specific to Moscow schools: synchronization of subgroups; handling of metagroups, and forbidden time slots for both teachers and groups. Soft constraints cover: minimizing gaps in teachers' schedules [2]; grouping similar lessons; balancing daily student workload; controlling lesson distribution across the week; enforcing double lessons; minimizing building transitions in multi-building schools; time slot preferences and limiting teacher workdays. The problem is characterized by mul- tiple conflicting objectives and institution-specific requirements, which significantly increase its complexity.

A hybrid algorithm combining greedy construction, local search, and exact MIP optimization is proposed. Numerical experiments on real school instances with up to 4000 lessons demonstrate efficiency with an expected runtime of 10 minutes per school.

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Dantzig-Wolfe decomposition in the CANOE energy model

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Abstract. The Capacity and Network Optimization Extension (CANOE) energy model [2] is considered. The model is a large-scale model and has a block structure. The solution of the model is based on the use of Dantzig-Wolfe decomposition [1]. To solve the resulting nondifferentiable optimization problem, it is proposed to use the simplex embedding method [4] in combination with zero-order methods [3]. A description of the algorithm and the results of a numerical experiment are provided.

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A Single Depot Multi-Trip Petrol Station Replenishment Problem with Dynamic Demands

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Abstract. The paper introduces a novel single depot multi-trip petrol replenishment problem with dynamic demands at underground reservoirs. Accounting for ongoing sales during delivery shifts expands the set of feasible trips and enables improved fleet utilization. We assume that each underground reservoir at each station can be serviced in one trip only and no two trucks may be present at the same station simultaneously. The truck's compartment closest to its cabin must be emptied last. The goal is to minimize the total size of the heterogeneous fleet of trucks for servicing all stations. In the preprocessing stage, we generate a large set of possible trips taking into account the dynamic demands and unloading constraints. For this set of trips, we formulate a new set covering model, solved both exactly and heuristically via column generation. The algorithms are tested on a semi-synthetic dataset to obtain upper and lower bounds for the fleet size.

On a method for ranking resources by their scarcity for a resource-constrained project scheduling problem

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Abstract. We consider a resource-constrained project scheduling problem (RCPSP) with respect to the makespan minimization criterion. The problem accounts for technological constraints of activities precedence together with resource constraints. Activities preemptions are not allowed. The problem with renewable resources is NP-hard in the strong sense. Metaheuristics are one of the promising methods for solving this problem. We propose a new method for identifying the most scarce resources, which helps metaheuristics to overcome these resource conflicts and find better solutions. The proposed resource ranking method was applied in a Genetic algorithm. Computational experiments with instances from the PSPLIB electronic library for J90 and J120 datasets showed its effectiveness. New solutions were obtained for several instances, and new best (previously unknown) solutions were found for one instance from J90 and four instances from J120 datasets.

Scheduling for Stability: Optimal Ordering and Unit-Buffer Placement on a Single Machine with Three-Point Duration Uncertainty

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Abstract. We study a stochastic single-machine scheduling problem without precedence constraints, motivated by production environments in which task durations are uncertain and schedule stability is critical. Each job's processing time is modeled using a symmetric three-point distribution centered on the nominal value, with one unit below and one unit above; the two extreme values are assumed to have equal probability. This simple discretization may serve as a coarse approximation of a normal-like variability model.

The operational protocol considered is a two-stage procedure. First, an initial (baseline) schedule is constructed using nominal processing times without idle times. Second, when actual durations materialize and the initial plan becomes infeasible, corrective rescheduling is performed by a right-shift procedure that preserves the original job sequence and prohibits advancing any job earlier than its planned start.

We introduce two stability measures to quantify deviations induced by uncertainty and corrective action: (i) the expected aggregate deviation of job start times in the realized schedule from their baseline planned starts, and (ii) the expected deviation of project makespan relative to the baseline. Our objective is to select a job ordering and to place a limited number of unit buffers so as to minimize these stability metrics. The main contributions are as follows. First, we propose an ordering policy that arranges jobs in nonincreasing order of an explicit job-level stability index, and we prove that this ordering is optimal with respect to the introduced stability criteria under the assumed uncertainty model and the right-shift correction policy. Second, for the case where a fixed number of unit buffers may be inserted in the baseline timeline, we derive the placement that minimizes the expected delay of project completion and characterize its structural properties. Together, these results provide constructive guidelines for creating baseline schedules that are resilient to small, symmetric duration perturbations while remaining operationally simple.

On a special case of the quasi-clique partitioning problem

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Abstract. Consider a simple graph partitioning into k quasi-cliques, (so called γ-cliques, $0 < \gamma \leq 1$), where each subgraph has density at least γ and order in given boundaries. The problem is to find a partition maximizing the value of γ.
It is seen that such a problem is an NP-hard one and we provide a mixed integer program to find the exact solution.
One of the applications of the described problem is as follows. Second-year students study first two years of university education in their academic groups and are to be redistributed into new groups for their third and fourth years. There are plenty reasons that lead to the necessity of such a redistribution. For instance, the results of the matching, the students of a curriculum and academic trajectories of this curriculum being the agents of the two-sided market.
In terms of graph theory, we have a graph $G(V, E)$ that consists of a given number of complete graphs (cliques) that are not connected to each other. Every clique of the graph corresponds to the academic group. Set of vertices V (the set of students) is subdivided into a given number of subsets and each subset, in its turn, is to be subdivided into a given number of quasi-cliques that corresponds to the new academic groups. An optimization criterion should be formulated for this redistribution and we advocate maximization of similarity between cliques and quasi-cliques. If one assumes this optimization criterion then the problem under consideration is to find vertices in V to be include into each quasi-clique such that the minimal density of quasi-cliques obtains its maximum value. Again, we provide a mixed integer program to find the exact solution of this problem.
Note that it is often the practical case when the number of quasi-cliques equals to two and both quasi-cliques have identical order. In other words, a set of students is to be subdivided into two new academic groups with identical size. A greedy algorithm is proposed to solve the problem under such assumptions. This algorithm is proven to produce a solution with at least 50% of optimal value of the objective function.
To verify both mixed integer program and greedy algorithm proposed in the paper, intensive numerical calculations were carried out on full-scale initial data provided by the Saint-Petersburg State University of Economics (Unecon).

A destroy and repair algorithm for the temporal knapsack problem

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Abstract. We have a set of virtual machines (VM) and a server with NUMA architecture. For each VM, we know its size, profit, time interval when it is active, and the CPU and RAM requirements. We need to find a subset of VMs and their location on the server to maximize the total profit under the server's CPU and RAM capacity constraints during the time horizon. To solve this NP-hard problem, a destroy and repair algorithm is developed. At the "destroy" stage, some VMs are removed from the current solution. At the "repair" stage, a new solution is created based on the Greedy and Tabu Search heuristics with penalties for capacity constraints. At the diversification step, we apply intersection with the best found solution. Computational results are discussed for semi-synthetic instances with up to 500 VMs.

Roman Coalition in Graphs[1]

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Abstract. Inspired by the defense strategies used to defend the Roman Empire, Cockayne and others [5] formally introduced the Roman domination problem (RDP) in 2004. The Roman domination problem is a combinatorial optimization problem on a graph asking to assign a label from {0, 1, 2} to each vertex feasibly, such that the total sum of assigned labels is minimized.
A coalition in a graph G consists of two disjoint sets of vertices A and B of G, neither of which is a dominating set but whose union A ∪ B is a dominating set of G. Such sets A and B are said to form a coalition. Coalitions in graphs were first introduced and studied in [6], and have subsequently been studied, for example, in [1, 2, 3, 4, 7, 8, 9].
In this work, we introduce and study the concept of Roman coalition in graphs arises from Roman domination in graphs.

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Spectral Diameter Upper Bounds for Special Classes of Polyhedra

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Abstract. Our report is devoted to the study of the combinatorial diameter of the graph of a polyhedron defined by a system $Ax \leq b$, where the matrix A consists of entries from {–1, 0, 1} and the vector b is an arbitrary real vector. We prove that, under the condition that the matrix A has at most two non-zero entries in each row, the diameter of the graph of the polytope is bounded by $O(n^{2.5})$, where n is the number of variables in the system. The bound can be refined to $O\left(n^2\sqrt{\min\{d_{max}, n\}}\right)$, where $d_{\max}$ is the maximum number of non-zero entries in the columns. The bound $O\left(n^2\sqrt{\min\{d_{max}, n\}}\right)$ also holds for the case where the matrix A contains at most two non-zero entries in each column and at most $d_{\max}$ entries in each row. This class of polyhedra generalizes a wide range of polytopes arising in specific combinatorial optimization problems, such as the transportation polytope, polytopes for matching problems in bipartite graphs, the fractional matching polytope for general graphs, fractional stable set polytope, fractional vertex cover polytope, polytopes for network flow and circulation problems, as well as the dual polyhedra corresponding to those listed above. For many of these polytopes, polynomial bounds on the diameter have already been established, and in some cases even linear bounds confirming the Hirsch conjecture, which, however, was disproved in general by Francisco Santos [3]. In certain cases, we are able to improve upon the currently known estimates. Considering the dual network flow polyhedra associated with b-flows on directed graphs $G = (V, E)$, we improve the known bound $\min\{(|V| - 1)\cdot|E|, \frac{1}{6}|V|^3\}$ by Borgwardt et al. [1] to $\tilde{O}(|V|^2 \cdot \sqrt{d_{max}}) = \tilde{O}(|V|^{2.5})$, where $d_{\max}$ is the maximum total degree of a vertex in G, and $\tilde{O}(\cdot)$ hides some poly-logarithmic terms. As a result generalizing the previous ones, we provide an estimate for the diameter of the graph of a polytope that is based on the spectral properties of a general matrix A. This estimate uses a connection between the diameter of the graph of a polytope and the geometric concept of the largest radius ball with its center on the unit sphere that can be inscribed into a polyhedral cone, discovered by Dadush & Hähnle [2]. To obtain our results, we derive an exact formula for the maximum radius of a ball (centered in the unit sphere) inscribed in a simplicial cone, and we also use the combinatorial properties of matrices with at most two non-zero entries in each row.

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Learning-Enhanced Security-Constrained Unit Commitment Problem

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Abstract. The Security-Constrained Unit Commitment (SCUC) problem determines day-ahead generator schedules for power systems while maintaining grid stability. It requires finding minimum-cost generator commitments that satisfy power flow limits and N-1 security criteria. The challenge is that these constraints create large-scale mixed-integer programs, which are computationally intensive due to their combinatorial nature and the need for precise integer solutions, making them difficult for standard solvers to handle efficiently. We combine machine learning with traditional MILP solving to speed up the solution process. In this study we use k-nearest neighbor warm starts, branching hints, and constraint screening to eliminate redundant security checks. The aim of this article is identifying such combination of solving techniques which provides the best solution characteristics (accuracy and spent time). Tests across multiple grid sizes show 10x speedups compared to baseline solvers.

Comparison of path generation techniques for optical network optimization

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Abstract. Routing and spectrum allocation (RSA) in elastic optical networks (EON) involves simultaneous path selection and contiguous frequency slot assignment, subject to spectrum continuityand non-overlapping constraints. This process is subject to spectrum continuity and non-overlapping constraints. This problem is NP-hard [1]. RSA is typically modeled using either node-link or path-link integer linear programming formulations [2, 3]. Node-link models associate binary variables with individual arcs and spectrum positions, resulting in flexible but large-scale formulations. Conversely, path-link formulations rely on predefined candidate routes, leading to more compact models whose computational efficiency critically depends on the quality of the candidate path set.

We explore whether efficient path-selection heuristics derived from node-link solutions can bridge the performance gap between these models. We hypothesize that structural information embedded within node-link flow variables can be systematically transformed into high-quality candidate paths. This transformation enables path-link models to improve spectrum utilization without the need for exhaustive path enumeration. Our heuristic framework extracts feasible routing paths from node-link assignments using constrained shortest-path reconstruction and spectrum-aware filtering.

The resulting paths are evaluated within a path-link RSA formulation. Computationalexperiments are conducted on standard benchmark transport network topologies [3], focusing on metrics such as blocking probability, maximum spectrum index, and computational runtime. Traffic demands are generated using a uniform distribution across admissible source-destination pairs and bandwidth requirements, providing a balanced test scenario. Variability is quantified using mean values and standard deviation across randomized demand sets. Results from computational experiments on standard benchmark topologies [3] show that node-link formulations can serve as both optimization models and informative generators of routing structure, providing a practical hybrid methodology for scalable RSA optimization.

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Worst-Case Thermal Security Analysis of Power System Operating Points

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Abstract. Assessment of thermal security margins is central to power system operation and planning. Standard methods usually track line loading or study transfer capability along predefined transaction directions. Such analyses can miss the injection changes that are most likely to trigger thermal violations. Related security-region and distance-to-boundary formulations quantify steady-state margins, but they do not directly identify the most critical perturbation direction for a given operating point [1, 2]. We therefore consider a worst-case formulation that characterizes the robustness of an operating point to arbitraryactive and reactive power injection perturbations.

We define a thermal security radius as the smallest perturbation in nodal injection space that causes at least one transmission line to exceed its thermal limit. Starting from a feasible AC operating point, we linearize the power flow equations locally through the reduced Jacobian. We then use adjoint sensitivity analysis to compute the dependence of line flows on injection perturbations. This yields, for each line and for the network as a whole, the most critical perturbation direction and the associated security radius. The resulting construction is closely aligned with inner-approximation and convex-restriction views of secure operating regions [2, 3].

The method provides a fast local security certificate and a principled way to rank lines by vulnerability to injection disturbances. Unlike transfer-based screening methods, it identifies the most critical disturbance directions directly rather than testing only predefined scenarios. Alongside the deterministic radius in the Euclidean norm, we also derive probabilistic measures that relate injection uncertainty to overload risk, consistent with broader uncertainty-aware power-system analysis frameworks [4].

Numerical experiments on standard benchmark systems show that the proposed metrics are effective and agree with Monte Carlo checks. The framework is suitable for rapid post-dispatch security screening and uncertainty-aware operational analysis, and it can be evaluated on open benchmark network libraries such as PGLib-OPF [5].

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Upper Bounds on Optimization Time of Genetic Algorithm on Royal Road Functions[1]

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Abstract. We consider a simple genetic algorithm (SGA) with fitness-proportionate selection, bitwise mutation, and crossover, and obtain up-per bounds on its expected optimization time on Royal Road function [4]. *E[T]* is the expected runtime, i.e. the expected number of individuals produced and evaluated until an optimal genotype is found for the first time. We first derive an upper bound on the expected optimization time of the SGA with mutation probability χ/n^2, where $\chi > 0$ is a constant, crossover probability $p_c < 1$, and population size $\lambda = \Omega(n \ln n)$, applying the improved level-based theorem of Doerr and Kötzing [2], we obtain $E[T] = O(n^2 a_1 \lambda \log(na_1) + n^{2r+1} a_1^{r+1} \log n)$.
In the case of crossover probability $p_c = 1$ and exponentially scaled fitness $d^{RR(x)}$ with constant base d such, that $d\varepsilon_{cr} > 5e^{\chi}$ (where ε_{cr} is a lower bound on the crossover gain), the level-based theorem of Corus et al. [1] yields $E[T] = O(n \lambda \ln \lambda + n^{r+1})$. This bound extends the linear-function result of [3] to all Royal Road functions and shows that the SGA with exponential scaling and crossover achieves a polynomial expected optimization time for any constant r.
At $r = 1$ both bounds reduce to the previously known estimates for linear functions from [3].
The results of experiments with the SGA with and without a single elite individual are also discussed.

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Zonal Control Synthesis with Memory for Rod Heating Process Under Partial Observability

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Abstract. This paper proposes a numerical approach for designing feedback controllers in distributed parameter systems, using a rod heating process as a case study. In this setup, the control inputs are the heating power levels of spatially localized heat sources along the rod. The controller uses feedback based on temperature readings at selected sensor locations and employs a zonal control strategy extended to include memory. In the memory-based zonal approach, the control law at time t depends on both the current observed state and a previous state from time $t-\Delta$, partitioning the augmented state space (current plus recent past) into discrete zones each associated with a fixed control value. Unlike continuously varying feedback laws, this zonal-with-memory strategy updates the control only when the combined state trajectory crosses a zone boundary, resulting in fewer adjustments. This discrete update policy reduces actuator wear and enhances robustness against uncertainties in the initial rod temperature and ambient conditions. The control design problem is transformed into a finite-dimensional optimization over the set of zonal control values. We derive explicit formulas for the gradient of the objective function with respect to these control parameters, enabling efficient gradient-based numerical optimization. A conjugate gradient projection method is used to iteratively tune the zone control values. Numerical simulations illustrate the feasibility of the proposed memory-augmented zonal controller and its ability to approach the desired terminal temperature profile with acceptable computational cost. The results also suggest how the inclusion of delayed observations influences the closed-loop behavior, including switching frequency and control effort.

Surrogate Modeling for Energy Optimization of Distillation Cascades

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Abstract. The rectification process remains one of the most energy-intensive operations in chemical engineering, where the optimization of interconnected column sequences is critical for reducing operational costs. Traditional rigorous thermodynamic simulations, involving the iterative solution of large systems of nonlinear MESH equations, often prove too computationally expensive or unstable for real-time global optimization tasks. This study presents a comprehensive framework for the energy optimization of a multi-column distillation cascade separating a ternary Benzene-Toluene-p-Xylene mixture, utilizing advanced data-driven approximation techniques to replace rigorous simulations.

The research explores the efficacy of diverse surrogate modeling paradigms to identify their respective strengths and weaknesses in process approximation. First, classical Deep Neural Networks (Multilayer Perceptrons) are employed as a robust baseline to approximate the response surface of the technological process. Second, Quantum Neural Networks (QNN) based on variational quantum circuits are investigated to evaluate their potential learning efficiency and generalization capabilities on limited datasets compared to classical counterparts. Third, Symbolic Regression is utilized to generate interpretable analytical expressions, facilitating the transition from "black-box" models to transparent "white-box" approximations that reveal underlying physical dependencies.

To address the safety risks associated with data-driven control, the study introduces a rigorous Formal Verification stage using Satisfiability Modulo Theories (SMT) solvers. This approach mathematically guarantees that the trained surrogates adhere to fundamental physical constraints, such as the monotonic relationship between the reflux ratio and energy consumption, ensuring the reliability of the control system.

The verified models are integrated into a Differential Evolution algorithm, demonstrating a reduction in computational time while maintaining high fidelity to the rigorous process simulation.

Occupation games with stable matching mechanism

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Abstract. In the marriage problem, the players' roles are fixed, while in the roommate problem, the players' roles are absent. In this article, we introduce occupation games, in which a player's strategy consists of choosing a role, type of occupation, and profession. In the occupation game, as in the roommate problem, players have strong preferences relative to each other. After the players have chosen their roles, we construct a corresponding marriage problem, in which a stable matching is found using a stable mechanism. Each player is interested in choosing an occupation type that ensures their most preferred pairing in the stable matching. It is proven that if the players' preferences are acyclic, then the occupation game has a strong Nash equilibrium. We show that any stable matching in the roommate problem corresponds to a Nash equilibrium of the proposed game if the stable mechanism selects it for some profile of players' strategies. Moreover, the set of matchings that correspond to an equilibrium of the game is not limited to stable matchings in the roommate problem. Thus, equilibrium in the occupancy game naturally generalizes the concept of stability in the roommate problem.

Removing multiple variables in the hybrid method for linear programming

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Abstract. In [Pirau, Hildebrand 2024] a hybrid method for linear programming has been proposed. This method is basically an interior-point method, but it may in the course of running decide that certain primal or dual variables cannot be zero in the optimal solution, and hence set the respectively dual variable to zero. Then the question arises how to update the current primal-dual feasible iterate when incorporating this new information. In the original work, only a single dimension can be reduced at a time. Here we show how to reduce multiple dimensions in a single step.

Entropy-Regularized Stochastic Optimal Scheduling of Battery Energy Storage Systems in High-Renewable-Penetration Microgrids

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Abstract. High penetration of renewable energy in distribution-level microgrids introduces significant stochastic variability in net load profiles, leading to reduced load factor and increased peak demand stress. This paper formulates the day-ahead battery energy storage system (BESS) scheduling problem as a constrained stochastic optimal control problem with continuous action space. The objective is to maximize daily load factor while satisfying state-of-charge (SoC), power balance, and operational constraints under uncertain photovoltaic generation. The problem is nonlinear and temporally coupled due to battery dynamics and charging/discharging complementarity constraints. Instead of relying on mixed-integer linearization, we adopt an entropy-regularized reinforcement learning framework based on the Soft Actor-Critic (SAC) algorithm. The scheduling task is modeled as a constrained Markov Decision Process (MDP), where the maximum entropy objective enhances exploration and improves stability in stochastic environments. The proposed approach is validated using real operational data from a renewable-rich campus microgrid with 50% photovoltaic penetration. Four representative operating scenarios are investigated. Simulation results demonstrate peak demand reduction of 7–25% and load factor improvement ranging from 0.095 to 0.229 while satisfying network constraints. The results indicate that entropy-regularized stochastic control provides a scalable and computationally efficient alternative to deterministic trajectory-based optimization for day-ahead scheduling in renewable-dominated microgrids.

On solutions to cooperative games

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Abstract. A little-known concept of the solution to a transferable utility cooperative game in characteristic form is discussed. In contrast to the core of the game this solution is always nonempty, and unlike the von Neumann-Morgenstern solution this solution exists in any cooperative game.
Moreover, if the core of the game is nonempty, then the considered solution coincides with the core. The examples of the solutions to some classes of cooperative games are adduced.

Two-stage facility location problem with CVAR criterion and constraints

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Abstract. A two-stage stochastic facility location problem is considered, taking into account consumer preferences. Consumer preferences are defined by a system of constraints, and demand for products is determined by random variables. In the first stage, before the demand is known, certain facilities are selected for opening, and in the second stage, after the actual demand is known, additional facilities can be added. The objective function of the problem is the Conditional Value-at-Risk (CVaR) of the company's profit, taken with the opposite sign (losses). This function describes the company's average losses under the assumption that these losses will exceed the level which can not to be exceeded with a given probability. Constraints on the CVaR of losses at lower probability levels are also considered, which can be interpreted as the losses in the worst-case scenario. The problem is solved using the method of sample approximations, which reduces the problem to a mixed integer linear programming problem. The convergence of the solutions of the obtained approximations is proven both in terms of the value of the objective function and the optimization strategy. The results of numerical experiments are discussed. Also a theorem on conditions for convergence of the approximation of a more general problem is proven, where the probability functionals such as mathematical expectation, the probability of an adverse event, VaR, and CVaR serve as objective functions and constraints.

Generating strongly efficient target for measuring efficiency in data envelopment analysis with integer data

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Abstract. Data envelopment analysis is an effective technique for measuring the relative efficiency of a set of production units that apply multiple inputs to produce multiple outputs. The idea is to use the relative distance of a production unit to its projection on the production frontier constructed from the set of production units as the measure of efficiency. For cases that the data must be integer values, such as the number of workers, the projection points may not be integer-valued, and is not practical to be a target for measuring efficiency. Various models have been proposed to generate integer-valued target to measure efficiency. However, the targets may be weakly efficient points, rather than strongly efficient points, which are not eligible to be a target. Based on the property that given a weakly efficient point there is at least one strongly efficient point that dominates this weakly efficient point, this paper proposes a model to generate the strongly efficient point that is closest to the given weakly efficient point to be the target to measure efficiency. Furthermore, the conventional radial efficiency is not reliable due to the effect of the non-Archimedean number used in data envelopment analysis. This paper adopts a Russell efficiency to take both the inputs that can be reduced and the outputs that can be expanded into consideration to express the performance of a production unit. The results are more representative and reliable. A case of efficiency measurement for thirty high schools is used to illustrate how the proposed model improves the shortcomings of the existing models.

A priority algorithm for solving a practical problem of transport logistics with a warehouse

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Abstract. We consider a vehicle routing and scheduling problem arising from the following applied logistics setting. Multiple enterprises are given, each operating a fleet of vehicles (20–40 vehicles per enterprise), where each vehicle operates according to a predefined shift schedule. Each enterprise operate a wholesale depot: vehicles deliver goods from the wholesale depot (shipping point) to retail locations (delivery points). Both shipping points and delivery points have limited throughput capacity. The delivery network consists of approximately 300 delivery points, each equipped with storage facilities of limited capacity for different types of goods and provided with forecasts of future demand for each type. The objective is to plan deliveries in such a way as to prevent both stock depletion and storage overflow at delivery points. For each vehicle, a route must be selected that prioritizes supplying storage facilities close to depletion, while maximizing the total volume of goods transported by the fleet. We formulate this task as a discrete optimization problem and propose a solution algorithm based on route prioritization. Computational experiments demonstrate that the proposed algorithm is capable of generating feasible vehicle routes within acceptable computation time, making it suitable for practical large-scale logistics applications.

On Approximations of Optimal Coverings on Algebraic Surfaces of Constant Curvature

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Abstract. Optimal coverings of surfaces arise in problems of sensor network deployment, approximation theory, and robotic path planning.
The paper focuses on constructing a minimal covering of a surface with equal circles, specifically for second-order surfaces of constant curvature: a sphere *S* of unit radius (positive curvature) and a right circular cylinder *C* of unit radius (zero curvature).
The distance between points is understood in the intrinsic metric, i.e., it is the minimum length of a curve connecting them on the surface. The optimality criterion is the minimization of the radii of the circles, given their number.
To solve the problem, we propose an iterative algorithm based on the construction of a generalized Voronoi diagram with respect to the geodesic metric. Each iteration consists of three steps: partitioning the given region of the surface into zones of influence of the points Voronoi cells; finding their generalized Chebyshev centers; and updating the Voronoi diagram. The algorithm proceeds until the Chebyshev centers reach a fixed point, i.e., until consecutive iterations produce identical sets of centers.
We provide estimates of the efficiency of the algorithms, depending on how much they change the coordinates of the points at each step, and study the properties of generalized Chebyshev centers. In particular, we derive conditions under which they are single-point sets, consist of anite number of points, or contain one-dimensional manifolds.
As examples, we consider the cases where M is a spherical segment or an annular strip on the cylinder.
The resulting coverings demonstrate the effectiveness of the propose dapproach. All found configurations are consistent with analytical solutions, where such solutions exist.

Fastest Route Construction in Anisotropic Media with Flows and Moving Obstacles

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Abstract. The paper addresses the problem of constructing minimum-time routes for moving objects in a dynamic environment subject to spatially inhomogeneous currents, static and moving obstacles. Real-time trajectory planning in realistic hydrological conditions is essential since neglecting environmental dynamics can significantly increase travel time or even render the mission infeasible.

Based on the Fermat-Huygens principles and the optical-geometric analogy, the time minimization problem is reduced to solving a generalized (anisotropic) eikonal equation. The minimum arrival time function satisfies this equation, and the optimal trajectories are recovered by backtracking along the gradient of the arrival time function.

For the numerical solution, we propose an iterative algorithm that modifies the Fast Marching Method to handle anisotropic environments with moving obstacles. The algorithm constructs a scalar field of arrival times from the start point to all grid nodes, taking into account the vector current field and obstacle constraints. At each time step, the algorithm accounts for the current positions of dynamic obstacles, ensuring collision-free motion.

A series of computational experiments is carried out for various scenarios: a stationary unidirectional current, two opposing flows, a vortex zone with tangential velocity, a combination of a vortex and horizontal currents, and the presence of dynamic obstacles moving along prescribed trajectories. For each scenario, optimal routes are constructed, and the influence of environmental parameters such as current velocities, obstacle sizes and trajectories on the path shape, and total travel time is analyzed. In addition, we compare the proposed approach with the heuristic Salp Swarm Algorithm (SSA). In all considered examples, our method yields shorter travel times with comparable or shorter path lengths. In particular, in the scenario involving a vortex and obstacles, it achieves a time gain by effectively utilizing favorable current components.

The results demonstrate that the proposed approach constructs trajectories that are near-optimal in terms of travel time while satisfying safety constraints, i.e., ensuring collision-free motion. All obtained configurations are consistent with qualitative physical reasoning about object behavior in a flow: the tendency to enter favorable currents, avoidance of opposing flows, and circumvention of vortex zones on the advantageous side.

Application of ADMM type solver for high-dimension optimization problems

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Abstract. Consider the following convex optimization problem, which is solved on a network:

$$\min_{x \in R^n} \sum_{i=1}^{N} \left(\frac{1}{2} x^{i\mathrm{T}} A^i x^i + b^{i\,\mathrm{T}} x^i \right), \tag{1a}$$

$$Cx \in [l, u], \tag{1b}$$

where $N > 0$ is size of the network (number of agents), $x^i \in R^p$ – subvector of x with p local variables of the agent i, $A^i \in R^{p \times p}$, $A^i \succ 0$ and $b^i \in R^p$ are local components of the objective function. Matrix $C \in R^{n \times m}$ is a matrix of constraints with each agent knowing its own part $C^i \in R^{p \times m}$, $C = [C^1, \ldots, C^N]$. In the presented work we present a modification of ADMM algorithm, that allows distributed calculation of the (1) solution despite presence of coupling results. The theoretical results are supported by detailed numerical experiments with $n \geq 1000000$.

Development of Test Instance Sets for the Robust p-Median Problem

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Abstract. This study presents the construction of specialized test instances for the robust *p*-median problem. The work addresses an extension of the classical problem formulation, where customer demand is an uncertain parameter and the objective includes maximizing solution robustness under a given budget constraint. Developing new algorithms for this problem requires test instances of varying complexity.

The article introduces new series of test instances with different dimensions (25, 35, 50, 100), based on the known "Discrete Location Problems" test library. A key feature of the constructed instances is a high duality gap, exceeding 99% for most cases of the robust version. This poses significant computational difficulties for exact methods based on linear programming and branch-and-bound. Experimental studies conducted on these test sets revealed that well-known commercial solvers may require up to 25 days to find and prove an optimal solution. In contrast, heuristic algorithms based on local search find solutions of comparable quality within a timeframe not exceeding 10 minutes.

The developed test instances serve as a tool for evaluating and comparing algorithms, as well as for identifying promising directions for creating problem-specific metaheuristics.

Ensemble algorithms for clustering and forecasting time series based on the Wasserstein distance[1]

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Abstract. This paper examines the problems of clustering and forecasting time series using a 4-year sample of daily electricity consumption profiles for a private household (a "smart home"). To identify consumption patterns, an ensemble clustering algorithm based on the Wasserstein metric was developed and applied. A normal distribution was assumed for each cluster. The developed clustering algorithm is adapted for time series, as it utilizes time features. Clustering quality was assessed using the Silhouette score; the optimal number of clusters yielding the highest index value was selected. An ensemble algorithm for short-term forecasting of the time series was also developed. For current daily observations, the closest cluster based on the Wasserstein distance was found. Then, the forecast for the future period was calculated as a weighted sum of the forecast of the closest cluster model and the forecast of the global model trained on the entire sample, but without dividing into clusters. The weights were updated dynamically, inversely proportional to the error over the past n days. The optimal number of clusters for the developed algorithm was shown to be consistent with that of baseline algorithms; patterns of daily profiles were obtained and interpreted. The ensemble forecasting algorithm demonstrated higher quality $RMSE$, $MAPE$ and R^2 metrics on the test sample compared to several other well-known forecasting algorithms.

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Double coloring of vertices to maximize the weighted number of stable edges

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Abstract. In the Max k-Edge-Colored Clustering problem we are given an undirected multigraph and k colors. Each edge of the graph has a color and a nonnegative weight. For a given vertex coloring, an edge is called stable if its color matches the color of its endpoints. The goal is to color the vertices so as to maximize the total weight of stable edges. The problem was introduced by Angel et al. [1]. We consider a modification of this problem in which vertices are allowed to be colored in two colors. We note that maximizing of the total weight of stable edges is equivalent to minimizing of the total weight of unstable edges. Thus, our problem is a weighted maximization version of the Locally-Budgeted Overlapping Edge-Colored Clustering problem with edge coloring for b = 2. The Locally-Budgeted Overlapping Edge-Colored Clustering problem with edge coloring seeks to minimize the number of unstable edges by assigning up to $b \geq 1$ colors to each vertex [2]. Let us call our problem the LB-MAX-k-EC problem.
It is easy to show that the LB-MAX-k-EC problem is strongly NP-hard by a reduction from the Max k-Edge-Colored Clustering problem. In this paper we give two polynomial-time algorithms for the LB-MAX-k-EC problem with an approximation factors $\frac{49}{18e} \approx 0.37$ and $\frac{4}{9} \approx 0.44$. Both algorithms use a similar two-phase scheme. They start by solving the corresponding linear program (similar but unique for each algorithm). On the first phase the algorithm chooses a set of desired stable edges randomly and independently for each color. On the second phase the algorithm colors vertices taking into account the selection of the edges made on the first phase. Although the approximation ratio of the first algorithm is worse than that of the second, the accuracy analysis of the first algorithm is significantly simpler than that of the second.

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STAP-CAP: forming groups with acquaintance constraints

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Abstract. We consider the STAP-CAP problem (Social Threshold Activity Placement with Capacity Constraints [1, 2]), a group formation problem in which users are assigned to activities under capacity constraints and social compatibility thresholds. A user can be assigned to an activity only if at least a prescribed number of their friends are assigned to the same activity. For each user and activity, a utility value is assigned, which is added to the objective function if the user attends the activity. The objective is to maximize the total utility of the feasible assignment.

We establish the computational complexity of the general STAP-CAP problem and its clique-based special cases. For the general problem, we show that the standard LP relaxation has an unbounded integrality gap and that the problem does not admit a polynomial-time α-approximation for any fixed $\alpha > 1$, unless P = NP. These negative results are obtained via reductions from classical NP-hard problems.

In the case where the acquaintance graph is a disjoint union of cliques, we present both approximation and exact algorithms. For every fixed integer d, we consider the restricted version that uses only d of the m activities. Solving this restricted problem exactly and taking the best solution over all d-subsets of activities yields a polynomial-time d/m-approximation algorithm. On the other hand, if the number of activities is part of the input, then the problem remains strongly NP-hard even when the utility is independent of the activity type.

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Counterfactual Routing for Explainable Accessible Navigation

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Abstract. We address the Counterfactual Routing Problem (CRP), motivated by the need to explain route recommendations for wheelchair users. A navigation service computes a shortest feasible route (fact route) respectinguser-specific constraints such as sidewalk width and curb height. When this route deviates from a shorter but infeasible alternative (foil route), the user may question the recommendation. The CRP seeks a minimal set of modifications to edge attributes so that the fact and foil routes become close enough. Reversing these modifications yields concise counterfactual explanations for preferring the fact route.

We propose three solution approaches. First, a mixed-integer programming (MIP) formulation that provides optimal solutions and proves optimality for 54% of the tested instances. Second, a best-first Tree Search (TS) framework that can operate as either an exactor a heuristic method. Third, a parallel Destroy-and-Repair (DR) algorithm, where multiple workers iteratively perturb and reconstruct solutions while sharing improvements across threads.

Computational experiments on real and generated instances show that DR achieves a 0.5% average gap to the best-known solutions, compared to 12% for TS, within a 5-minute time limit. The algorithm was a runner-up in the Counterfactual Routing Competition at IJCAI-25. Retrospective experiments on the 41 competition instances show that it finds the best-known solution in every run once a sidewalk width lower bound is relaxed, achieving an average rank of 1.0. In the best solutions, most modifications adjust accessibility attributes on edges where the fact and foil routes diverge; when reversed, they pinpoint the specific physical barriers that justify the recommended route.

On regularization parameter for Lasso optimization in graphical model selection

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Abstract. Graphical model associated with a random vector $X = (X_1, X_2, \ldots, X_n)$ is usually understood as an undirected graph reflecting a conditional dependence structure of the components of X. Graphical models attract a growing attention in data analysis and machine learning due to the wide area of its applications. The Graphical Model Selection Problem (GMSP) consists of recovering this conditional dependency graph structure from observations. Different algorithms to solve this problem were developed and their properties were investigated (see Cordoba et al. [3], Drton and Maathuis [4]). Uncertainty of an algorithm is measured by error in recovering a true graph structure from observations. One popular class of graphical lasso (GL) algorithms is related with l_1 regularization of maximum likelihood estimator for the inverse of covariance matrix Banerjee et al. [1], Friedman et al. [5]. Choice of the regularization parameter is crucial for the uncertainty of GL algorithm.

Theoretical studies of the GL algorithm and its uncertainty are mostly concentrated on the good choice of regularization parameter depending on the problem dimension and on the sample size Banerjee et al. [1], Meinshausen and Bühlmann [8] to ensure consistency of the algorithm. Practical choice of regularization parameter is related with cross validation techniques or robust formulation of the associated optimization problem Cisneros-Velarde et al. [2].

On the other hand, an important graph characteristic is its density. The main aim of this paper is to explore a connection between the uncertainty of graphical model selection algorithms and the density of the underlying conditional dependency graph. This topic has not received much attention in the literature. Some preliminary results for multiple hypothesis testing selection algorithms were presented in Kalyagin and Kostylev [7].

In the present paper we investigate uncertainty of GL algorithm in connection with density of underlying conditional dependency graph. Our methodology is based on the general approach for uncertainty analysis of graph structures in random variable networks Kalyagin et al. [6].

First, we study dependence of uncertainty of model selection by GL algorithms on graph density. Surprising observation, that we get from this study, is that for a fixed regularization parameter the density of the graph resulting from GL algorithm is stable independently on density of underlying conditional dependency graph. This phenomenon seems to be more general and can be associated with l_1 regularization, but we did not find in the literature a theoretical foundation of such general fact. Clearly, l_1 regularization imposes some portion of zeros in the resulting concentration matrix (connected with graph density), but apriori it is not clear whether this portion will be stable. The observed phenomenon shows that GL algorithm has a systematic uncertainty bias due to a difference in graph's density.

Next, for a fixed problem dimension and a sample size, we find a relation between the density of conditional dependency graph and the regularization parameter such that the density of graph produced by GL algorithm coincides with the

density of conditional dependency graph. It allows us to smooth the density bias and make a "fair" evaluation of uncertainty. As a result we observe that the proposed choice of regularization parameters produces a good positive effect on uncertainty of GL algorithm. This positive effect is more significant for a small values of density, which is understandable since the GL algorithm was designed for sparse graphs in the first place.

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Optimal Epidemic Control with Capacity-Constrained Resource Allocation

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Abstract. The effective control of epidemic outbreaks presents a dual challenge: identifying efficient intervention strategies and allocating limited medical resources in real time. This paper proposes a two-stage framework for epidemic control that combines continuous optimal control with discrete resource allocation. The epidemic dynamics are described by a Susceptible-Exposed-Infected-Recovered-Dead (SEIRD) compartmental model, which captures both the latent stage of infection and disease-induced mortality.

At the first stage, a classical optimal control problem is formulated and solved for two time-dependent interventions: vaccination and treatment. Vaccination transfers individuals from the susceptible compartment to the recovered compartment, while treatment increases the recovery rate of infected individuals. The objective is to minimize the total cost, which takes into account the infected population, mortality, and the costs of vaccinating and treatment. Pontryaguin maximum principle is used to derive optimal control strategies over a fixed time horizon.

Since this continuous model does not reflect the discrete and capacity-constrained nature of healthcare systems, a second stage is introduced. It is based on the Potential Values Method, which interprets the treatment control obtained at the first stage as demand for medical services. This demand is then distributed among a finite set of medical facilities subject to throughput and capacity constraints. The resulting allocation problem is formulated as a minimax integer optimization problem aimed at balancing facility workloads and preserving reserve capacity. Numerical experiments illustrate the effectiveness of the proposed framework for integrating epidemic control and healthcare resource allocation.

Numerical Local Search for Epidemic State-Nonconvex Optimal Control Problems[1]

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Abstract. We address an epidemic optimal control (OC) problem with a state-linear control system and the goal Bolza functional given by DC (difference of convex) functions in the terminal and integrand parts. Thus, the noncovexity of the problem is produced only by the state-DC cost functional. The idea of the OC methods is suggested by the well-known DCA algorithms from the finite-dimensional, so-called Global Optimization and consists in a consecutive solution of the linearized OC problem at every iteration. Thanks to this ideology, one refers to this class of methods as the Current-Phan Din TaO methods. The advantage of this approach is due to the possibility of solving the linearized OC problem with the help of the PMP (Pontryagin's Principle) method, because the PMP provides not only necessary, but also sufficient Optimality Conditions for this problem with convex reachable set.
The convergency of such Special Local Search Method (SLSM) is also investigated, which provides,in particular, a relevant stopping criterion. The SLSM was successfully tested on a number of applied examples of epidemic OC Problem, on which the SLSM demonstrated some advantages and shortcomings relatively to other approaches. After some corrections, we are going to develop a Global Search approach based on well-known Global Optimality Conditions.

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A method of scaling variables in large-dimensional optimization problems

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Abstract. Minimization problems often require methods capable of solving large-scale problems under noise. Such methods exist today, for example, the ADAM algorithm. However, there is no theoretical basis for its acceleration properties, although these properties, acquired through the use of metric matrices, have been demonstrated experimentally.

The goal of this study is to formulate a minimization method that utilizes variable scaling to accelerate convergence using adjustable diagonal matrices and is suitable for solving problems with noise.

In this paper, we present a prototype of a new method with finite convergence on quadratic functions and investigate its properties. The origins of this prototype lie in the field of subgradient methods. The main goal of a subgradient method is to find a direction that can lead beyond the neighborhood of the current point as a result of one-dimensional descent. Here, we use a method developed on these foundations, which, in the case of quadratic functions, constructs a sequence of conjugate vectors. In conjugate gradient methods (CGM), previous gradients are orthogonal to the new conjugate direction. That s, each new descent vector leads the method to a new subspace. The metric matrices in the new method suppress the eigenvectors of the subspace of previous gradients. Because CGMs lose their orthogonality properties due to roundoff errors, the property of suppressing the presence of eigenvectors of the subspace of previous gradients when using a metric matrix positively affects the convergence rate. In this study, a diagonal metric matrix is used for these purposes.

The prototype was transformed into a minimization method suitable for solving large-scale problems, robust to noise, and not requiring a one-dimensional search. A design for a method with variable scaling using diagonal metric matrices was defined. Step adaptation, which has proven effective in various minimization methods for solving minimization problems, including those with noise, was used to select the step factor of the minimization method. The algorithm was developed using ideas from modern stochastic gradient methods. The resulting algorithm has the structure of the ADAM algorithm with step adaptation, and its metric matrix transformations are largely similar to the ADAM algorithm metric. The new algorithm was numerically studied on test functions and compared with the well-known ADAM method with step adaptation. The experiment showed that the minimization method is effective for solving problems with noise and poor variable scaling.

Configurable Optimization for Complex Industrial Problems with LLM-Based Adaptation

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Abstract. Real-world combinatorial optimization problems in industrial settings are rarely defined by a single fixed formulation. Business rules vary across customers, new constraints emerge at deployment time, and operational parameters change between planning periods. Standard solvers require manual reformulation for each variant, and general-purpose black-box frameworks fail to exploit the underlying problem structure. We propose a multi-agent optimization framework in which each agent solves a distinct subproblem and is independently configurable. The key contribution is a three-level business rule encoding that separates concerns without requiring solver redesign: shared structural constraints are hardcoded in the solver core, customer-specific logic is injected at runtime through an expression evaluation layer, and user-facing parameters are exposed via declarative configuration files. This architecture allows new constraints and objectives to be incorporated at the appropriate level without modifying the optimization algorithms.

To handle business rules not known in advance, the framework integrates large language model (LLM) agents that interpret natural language requirements and directly produce validated configuration updates and runtime logic injections. An automated pipeline checks the generated artifacts for correctness and compatibility before deployment. This allows non-expert users to reconfigure the optimization model for new business scenarios without manual solver reprogramming.

We demonstrate the framework on a large-scale delivery scheduling problem related to the resource-constrained multi-project scheduling problem (RCMPSP), where sites must be clustered and assigned to monthly periods under material, contractor, and activation constraints. The three-level architecture has been successfully reconfigured for multiple customer-specific problem variants without changes to the optimization core.

Towards Constant Adaptivity Gap for the Stochastic Orienteering Problem[1]

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Abstract. The Stochastic Orienteering Problem (SOP) is a well-known non-deterministic variant of the classic NP-hard Orienteering Problem, which is aimed to collect the maximum reward by visiting nodes of an edge-weighted transportation network within the given traveling budget. An instance of the SOP is given by a finite pseudo-metric (V, d), where $d: V^2 \to Z_+$ and each node $v \in V$ is associated with a job of some deterministic reward r_v and random duration S_n drawn independently from some discrete distribution. Each reward r_v is collected (at most once) after the visiting node v and completion the associated job without preemption. The goal is to provide *a policy* ensuring the maximum expected reward within the given time budget B spent both for traveling between nodes and completing jobs.

In the literature, two types of policies *non-adaptive* and *adaptive* are distinguished. While a non-adaptive policy visits nodes in some fixed order established a priory, an adaptive one makes a choice of a next node to visit by taking into account realizations of random durations of the jobs completed to the moment. Since adaptive policies are much more powerful, any optimal solution of the SOP is of this type. On the other hand, all the known approximation approaches for the SOP and related problems are relied on non-adaptive policies, since finding a good adaptive policy relates to a huge time consumption.

Approximation ability of non-adaptive policies is measured in terms of *adaptivity gap*, i.e. the maximum ratio between the expected reward of an optimal adaptive policy and expected reward of the best non-adaptive one. For the general case of SOP, theoretical lower and upper bounds for the adaptivity gap are $\Omega\left(\sqrt{\log \log B}\right)$ and $O(\log \log B)$, respectively.

In this paper, we describe a non-trivial class of pseudo-metrics, for each of them adaptivity gap is constant and can be achieved in polynomial time.

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Optimization of Instruction Scheduling for VLIW Processors

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Abstract. The problem of constructing an optimal instruction schedule for processors with VLIW (Very Long Instruction Word) architecture is considered. A set of machine instructions forming a data dependency graph is given. For each instruction, the type and amount of required resources, as well as the latency – the delay before the result becomes available – are known. The processor contains a limited number of functional units (FU), which are assumed to be occupied only during the issue cycle. The goal is to assign each instruction a start time and a functional unit such that data dependency constraints are satisfied (a successor instruction cannot start execution before the results of all its predecessors are available) and resource constraints are respected (the total resource consumption in each cycle does not exceed the available capacity). The objective is to minimize the total execution time of the instruction bundle. The problem is NP-hard.

To solve the problem, an integer linear programming model proposed in [1] is used. Approximation algorithms based on simulated annealing and tabu search heuristics have been developed. An initial feasible schedule is constructed using a greedy list scheduling algorithm. To search for feasible solutions in the neighborhood, a reassignment operator is proposed: for a selected instruction, it searches for the first feasible slot on the current or an alternative functional unit within a time window bounded by the execution times of predecessor and successor instructions. Effective parameter values for both heuristics were experimentally tuned. The algorithms were implemented in Python. The results of computational experiments on dependency graphs of real software packages containing up to 300 instructions are discussed. A comparison is presented between the quality of the obtained solutions and the running times of the heuristics and the exact solution produced by the Gurobi solver.

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The Stackelberg model and the design of Russian subsoil use institutions: a methodology for solving practical problems

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Abstract. The report analyses key issues in cooperation between the government and private investors in a resource-rich region with significant deficiencies in transport and energy infrastructure. The lack of effective public-private partnership institutions (rules of interaction and mechanisms to ensure compliance with these rules) is most acute here, and the institutional features of the process of shaping the investment climate are playing an increasingly important role. These factors primarily include high transaction costs, which generally remain outside the scope of management. The imperfection of existing state institutions regulating the extraction of natural resources leads to an underestimation of this aspect of the problem and ignores the fact that the mechanism of interaction between high transaction costs and the principles of economic policy formation is quite complex and requires special tools.

The report formulates the basic methodological principles of institutional design in subsoil use, based on the Stackelberg game. The key elements of the methodology are the Stackelberg model in the form of a bilevel mathematical programming problem; a set of metaheuristics that allow solving large-scale problems; principles for forming a database using predictive simulation models; and a method of numerical experimentation based on scenario analysis.

The possibilities of this approach are demonstrated by the example of forming a consortium of subsoil users that would undertake the construction of the necessary public sector production infrastructure (railways, motorways, power lines) and the subsequent development of the region's natural resources. To this end, a triad of models is formulated, covering the most economically interesting organizational forms of such collaboration between the government and business. Based on information from the Trans-Baikal Territory, a comparative analysis of the equilibrium solutions of these models is carried out under different assumptions regarding the scenario of external conditions.

On an approach based on local search for solving the bi-criteria robust p-median problem

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Abstract. This paper is devoted to a variant of the well-known classical *p*-median problem, where parameters may change during long-term planning. Customer demand is considered an uncertain parameter. In addition to cost minimization, as in the classical p-median problem, this version requires accounting for the robustness of the obtained solution to potential changes. The situation is modeled using a bi-criteria integer programming formulation. An approximation of the set of Pareto-optimal solutions is constructed. To achieve this, an approach for solving the bi-criteria robust *p*-median problem is developed. It is based on a local search procedure with variable neighborhood search and consists of two stages: first, robustness is maximized, then costs are minimized. The transition between stages occurs after reaching a local optimum for the first criterion. Experimental studies are conducted on large-scale problem instances and specially created test series. For a comparative analysis of solution quality, evolutionary algorithms are adapted in this work.

Attack-Defense Game Model with Testing

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Abstract. The paper examines a model of Colonel Blotto's popular game in the form, proposed by Sonin, as a testing game. The model involves a number of objects of varying value, defended by one player (the "Defender"). The other player (the "Attacker") first tests all the objects, obtains imperfect information, and then attacks the objects. We study the problem as a matrix game between the Attacker and the Defender, allowing one to find equilibrium strategies for both the Defender and the Attacker. Target heterogeneity and test signal quality (sensitivity a and specificity b) jointly determine the optimal strategy selection of both Attacker and Defender. An analysis of the equilibrium strategies is provided, depending on the quality of the information received.

Leverage-Enhanced Multilinear Extension Sampling for Cooperative Game-Based Explainable AI

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Abstract. Recently, the Shapley value has been widely applied in machine learning for feature importance analysis and model explainability. The multilinear extension of games proposed by Owen expresses the Shapley value as the integral of partial derivatives along the main diagonal, but directly evaluating this integral still requires exponential-time computation of the partial derivatives for general cooperative games. To improve computational efficiency, we propose a sampling-based estimation strategy within Owen's multilinear extension framework, combining stratified sampling with coalition leverage scores. Specifically, we first select equally spaced quadrature points on the integration interval [0,1]. At each quadrature point, coalitions are stratified by size. Naive Bernoulli sampling concentrates almost all samples at coalition sizes near the binomial mode, because the number of coalitions of each size grows combinatorially. To counteract this concentration, we weight each stratum by the inverse coalition count, a quantity closely related to the leverage scores arising in the regression formulation of Shapley value estimation, so that the resulting sample allocation depends only on the percoalition Bernoulli probability, which varies smoothly across sizes. Within each stratum, coalitions are sampled uniformly and reweighted via importance sampling to ensure unbiased estimation of the partial derivative. Finally, Simpson's rule is used to integrate the estimates across all quadrature points, yielding an approximate Shapley value. Experimental results demonstrate that the proposed method significantly reduces computational cost while maintaining explanation accuracy.

On Dual and Inverse Problems in Single-Machine Scheduling

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Abstract. Duality plays an important role in scheduling optimization, primarily as a source of bounds and algorithmic insights. In most scheduling problems, however, duality is used only indirectly through relaxations such as Lagrangian or LP relaxations, while explicit dual formulations for the original discrete models are rarely considered.

A structural approach to this question was proposed in [1], where dual problems were introduced for a single-machine scheduling model with release dates and the maximum penalty objective. In that framework the dual problem takes the form of a max-min problem corresponding to the original min-max objective.

In this work we extend this approach to several classical single-machine scheduling models with min-sum objectives and without precedence constraints. For each problem we formulate the corresponding dual problem of the sum-min structure and study its structural properties. We prove that the dual formulations provide valid lower bounds for the original objectives (weak duality) and can be computed in polynomial time.

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Genetic algorithm for multi-period petrol station replenishment problem

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Abstract. This work considers a new variant of multi-period petrol station replenishment problem, in which a heterogeneous fleet of fuel trucks delivers petroleum products to a set of petrol stations over a planning horizon. Each truck can complete up to 2 trips per shift. The objective is to minimize the total distance travelled by trucks.

We developed a genetic algorithm for the approximate solution of the problem. Offspring solutions are improved with local descend that can both move station visits between shifts and move or swap stations between routes within a single shift. The algorithm can arbitrarily redistribute delivery volumes between visits of a station in order to improve the local descend landscape.

We developed a fleet minimization scheme that repeatedly solves the problem on different subsets of the original fleet. The algorithm is implemented in Zig and provides solutions for test instances with up to 65 stations and up to 10 shifts.

About the problem of planning production investment projects

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Abstract. A production investment project is understood as a set of technologically interconnected jobs aimed at generating profit. Each job is characterized by its duration and a cash flow. The technological dependencies are defined by a partial order on the set of jobs. The goal is to determine job completion times that maximize the project's net present value.
Traditionally, optimal scheduling accounts for allocated project resources. This paper adopts a different approach. First, all resources are converted into their financial equivalents, and for each job, a cash flow. In the first part, we assess the project's potential under no resource constraints. Optimal scheduling in this case requires solving an optimization problem with linear constraints but a nonlinear objective function. The model is implemented in GAMS. We propose a linear approximation of this model and conduct numerical experiments.
Next, we address project financing optimization. The main funding sources for an investment project are equity, loans, and co-investor funds. We propose an algorithm to maximize the owner's profit from project implementation.

Application of a Genetic Algorithm to the Problem of Optimizing the Lifetime of Power Plant Equipment[1]

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Abstract. As is well known, the energy sector is one of the leading sectors of any country's economy. According to [1], as of 2023, 54% of installed capacities in the Russian Federation exceeded the limits of their normative lifetime. In this regard, the relevance of assessing the condition and modernization of the energy infrastructure is undeniable.

The work addresses the problem of updating equipment of a large (aggregated) power system. Methodologically, ensuring power supply is a complex issue, as it requires accounting for the technical aspects of equipment operation. The mathematical model is constructed on the non-classical vector Volterra integral equation of the first kind. The main feature is the variable lower and upper limits of integration, which allows capturing the dynamics of the aging structure of the equipment. The formulation takes into account three types of generation with division of equipment by age groups and corresponding techno-economic characteristics [2].

The work continues the research started in [3], where the genetic algorithm, which is one of the most effective methods of evolutionary modeling, is used to solve the problem.

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A Fast Heuristic for the Periodic Petrol Station Replenishment Problem[1]

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Abstract. We introduce a new periodic petrol station replenishment problem over a given planning horizon, originating from a Russian petroleum company. We have the heterogeneous fleet of trucks and a set of petrol stations. We assume that each underground reservoir at each petrol station can be serviced in only one trip of the truck. The truck's compartment closest to its cabin must be emptied last. For each reservoir, we know its capacities, initial amount of petrol, and its sales for each hour per day. The goal is to minimize the total size of fleet to service all the stations, no reservoir should be empty within the given planning horizon. Our fast heuristic generates trips for the trucks day by day applying the column generation approach. The method is tested on a semi-synthetic dataset for Novosibirsk region.

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Network equilibrium with transmission capacity constraints[1]

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Abstract. Consider a network with producers and consumers of some homogeneous product. Suppose that a network equilibrium exists when there are no constraints on the amount of the product transmitted through the lines of the network. If we add transmission capacity constraints to the model, it may have one or multiple equilibria, or no equilibria at all. Thus these constraints play an essential role, making the search for equilibrium in the model a challenging task. An approach for finding equilibrium based on nonconvex optimization techniques is proposed.

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Multi-Agents Approach to Delivery System Optimization Problem

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Abstract. A multi-agent system to optimize the delivery process in complex projects is considered. The system has three specialized agents collaborating for efficient and synchronized execution. The Cluster Planning Agent determines the optimal performing period for each cluster subject to its constraints. The aim of the Site Planning Agent is to assign specific start dates for individual sites, adhering to the cluster's execution window, ensuring sufficient material and subcontractor availability. Lastly, the Material Planning Agent evaluates material availability and identifies necessary replenishments. These agents solve their optimization problem independently by suitable constructive methods or heuristic routines, but have the binding variables. Therefore, on the basis of consensuses alternating direction method of multipliers' idea, we developed a heuristic approach which allows us to find optimal solution in the multi-agent system. We optimize the objective function of each agent used (squared) regularization to pull each binding variable towards the average variable value. If an agent variable value is bigger or less than the average, then the regularization in the next step pulls it even closer. The method enhances clusters and sites starting and delivery process efficiency and ensure resource alignment across time and supply materials.

Minimizing durations of multiple subprojects on identical parallel machines

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Abstract. A problem of scheduling jobs on identical parallel machines is considered. Each machine can process at most one job at a time, and job preemption is not allowed. All jobs have equal processing times and are grouped into subprojects. Among the schedules that minimize the makespan, it is necessary to find those that also minimize the total duration of the subprojects. This objective is motivated by scenarios where completing a subproject requires additional leased resources, or where the subproject's duration directly impacts overall project quality. We also consider the problem of minimizing the maximum deviation of subproject durations from the minimum possible ones on the set of the shortest schedules. This formulation addresses the issue of equitable resource allocation among subprojects.

The study investigates the computational complexity of various problems versions, depending on the presence and structure of precedence constraints between jobs. We analyze key properties of these problems and propose exact solution methods based on dynamic programming.

Gridless methods application for mean field game coefficient inverse problem

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Abstract. The work considers the application of two gridless methods – the collocation method and physics-informed neural networks – to the coefficient mean field game problem. The chosen mean field game model is designed for optimal control problems involving a large number of players. This approach reduces these problems to a system of parabolic equations, part of which are solved backward in time with terminal conditions. We implement this approach for the SIR epidemiological model to model and estimate the social response to an outbreak. The inverse problem involves finding the parameters of the model using additional given data. We study the identifiability and sensitivity of the SIR mod- els, as well as the well-posedness of the inverse problem in relation to different types of available data.

We present a numerical comparison results between the physics-informed neural networks and the collocation method. These methods allow us to solve the forward-backward system in time without additional complications, as we solve the equations in over the whole domain at once. We present a comparison in terms of achieved error levels for different sets of additional data, levels of noise, and parameters of the methods. This analysis enables us to introduce and investigate necessary regularization approaches for ill-posed and unstable setups that lack sufficient data.

Reliable Multi-commodity Hop-constrained Network Design Problem: Formulation and Branch-and-Cut algorithm

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Abstract. Reliable network design problems are the well-known and challenging field in operations research, with a wide range of industrial application including resilient supply chain management and fault-tolerant telecommunication networks. Problems in this domain typically involve finding a trade-off between two conflicting criteria: ensuring network reliability and minimizing overall cost. In this paper, by extending both the recent results of O. Arslan and G. Laporte for network design with vulnerability constraints and our results for the Efficient 2-Terminal Reliability Problem in the general context of chance-constraint optimization, we introduce the Reliable Multi-commodity Hop-constrained Network Design Problem (RMHNDP). In this problem, we are given by a network with edge transportation costs and Erdos-Renyi probabilities, several dedicated origin-destination pairs, upper bounds $H1<H2$, and a reliability threshold η. It is required to find a minimum cost sub-network, in which any O-D-pair is connected by a primal path of at most H1 edges, and all of them are supplemented by backup paths of at most H2 edges with probability η. Relying on the well-known combinatorial Benders decomposition approach, we propose MILP-formulation for the RMH-NDP that incorporates novel families of valid inequalities, conditions of their ability to be facet-inducing, and appropriate separation problems. As a result, we obtain a branch-and-cut algorithm and prove its high performance by the results of numerical experiments.

On solving the Bilevel Optimization Problem of Import-Export of Coal Resources[1]

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Abstract. The work addresses the economic relations between the importer and exporters of coal resources in the form of a bilevel optimization problem, where at the upper level, the importer sets prices (and, possibly, additional tariffs) to each supplier country for each type of coal resources (e.g. thermal coal, coking coal, anthracite). And at the lower level, suppliers determine the quantity of the provided product, in consideration of their costs and supply capabilities. The upper-level aims to minimize the costs of each product type, taking into account meeting itself needs. The goal of each exporter is to maximize its profit, given the established prices and tariffs, as well as their own production costs and supply capacity. The importer has its own potential to provide itself with coal, but it is insufficient for full coverage its own needs yet and/or is quite expensive in terms of cost price. The model we propose does not consider how exporters provide themselves with coal resources (we assume that this issue has been solved and surpluses are offered to the market for sale).

To develop numerical methods for the considered problem, we begin by reformulating the bilevel problem as a single-level nonconvex optimization problem, substituting the lower level with its KKT-optimality conditions. Next, we apply the Exact Penalization Theory along with the Global Search Theory (GST) to tackle the transformed problem. GST involves expressing nonconvex functions as DC representations (that is, as the difference of two convex functions) and constructing both local and global search methods tailored to the distinct features of the examined problem. Computational testing of the developed methods demonstrated the efficacy of the approach proposed.

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Relaxation algorithms for multi-period petrol station replenishment problem

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Abstract. This work considers a variant of the multi-period petrol station replenishment problem. A set of petrol stations, fuel trucks, and multiple fuel types are given. Distances between stations, fuel consumption rates, compartment configurations for each truck, and initial fuel levels in underground tanks are known. The planning horizon requires that stockouts are avoided and total delivered fuel meets demand. Each route starts and ends at the depot, with trucks departing fully loaded and returning empty. The objective is to minimize the total distance traveled.

A mixed-integer linear programming model is formulated, and various methods for obtaining feasible and relaxed solutions are proposed. Different relaxations of the original problem are considered. The resulting problems are solved either exactly or heuristically using the Gurobi solver. Additionally,an approach based on solving a series of smaller subproblems is developed to improve an existing feasible solution. The algorithm is implemented in Python. Computational results on real-world data are presented.

Coded and Verifiable Distributed Computation for Trustworthy Machine Learning

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Abstract. Machine learning is increasingly deployed over distributed and weakly trusted infrastructures, where communication overhead, node churn, stragglers, and adversarial behavior can degrade both efficiency and reliability. Federated learning keeps raw data local, and blockchain-based coordination can improve auditability and incentive alignment, but neither paradigm by itself provides a general mechanism for robust computation in the presence of partial participation and Byzantine workers [1,2].

This work investigates coded distributed computation as a unifying abstraction for trustworthy machine learning. Instead of relying on replication-based redundancy, training and inference tasks are encoded across workers so that the target output can be reconstructed from a sufficiently informative subset of returned computations. Building on classical coded computing and recent learning-theoretic formulations, the proposed direction combines coded redundancy with lightweight cryptographic verification: workers return computations together with efficiently checkable evidence of correct execution, and the aggregator filters invalid responses before decoding the final result [3, 4, 5]. This formulation aims to provide graceful degradation under stragglers and partial participation, while exposing an explicit reliability signal for downstream decision-making.

A complementary direction applies the same principle to decentralized data storage. Datasets are represented as coded shards augmented with integrity metadata, enabling verify-before-use retrieval, reconstruction from any valid subset above the recovery threshold, and auditable storage over decentralized infrastructure. Overall, the work connects coding, verifiable computation, and decentralized coordination into a single systems framework for machine learning that remains operational under failures, partial participation, and adversarial interference.

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Cooperative Behavior in Dynamic Network Games Including the Change of Communication Structure

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Abstract. Consider a class of *n*-person differential games on the network with game horizon $[t_0, T]$. $N = \{1, 2, \cdots, n\}$ is the set of players (nodes) in the network. Let $x^i(\tau) \in R^m$ be the state variable of the player $i \in N$ at time τ, and $u^i(\tau) \in U^i \subset R^k$ control variable of the player $i \in N$ where U^i is a compact set.

At t_0, players choose neighbors simultaneously and independently with whom they intend to interact during the game. The player *i* can choose neighbors from a fixed subset of players $N_i \subset N\backslash\{i\}$. The sets N_i can be different for different players, and for each player *i*, the number of its possible neighbors is limited by the number n_i. Communication is established (that is, the link is created in the network) between players *i* and *j* if $i \in N_j, j \in N_i$. The resulting network G is called *admissible network* [2, 3].

Denote the set of all arcs in network *N* by *P*. $P = \{arc\ (i, j) : i, j \in N, i \neq j\}$.The set of players connected to the player *i* is $K(i) = \{j : arc(i, j) \in P\}$, for $i \in N\ (K(i) \subset N_i)$.

The state dynamics of the game is

$$\dot{x}^i(\tau) = f^i(x^i(\tau), u^i(\tau)), x^i(t_0) = x_0^i, \text{ for } \tau \in [t_0, T] \text{ and } i \in N \qquad (1)$$

Functions $f^i(x^i, u^i)$ are continuously differentiable in x^i and u^i and satisfy the conditions of existence, uniqueness, and continuability of the solution on the interval $[t_0, T]$ for all admissible piecewise continuous controls with a finite number of discontinuity points. For notational convenience, we use x(t) to denote the vector $(x^1(t), x^2(t), \ldots, x^n(t))$ and $x_0 = (x_0^1, x_0^2, \ldots, x_0^n)$(in [1]).

We consider a special case where the payoff of player i depends on his state variable and the state variables of players from the set K(i). Thus, if the connections remain valid, the payoff of the player i is given as

$$H_i(x_1^0, \ldots, x_n^0, u^1, \ldots, u^n) = \sum_{j \in K(i)} \int_{t_o}^{T} h_i^j \left(x^i(\tau), x^j(\tau)\right) d\tau, i \in N \qquad (2)$$

provided that the players do not interrupt communication. It is suppose that functions $h_i^j \geq 0$. In case, the player *i* interrupts the communication with player *j* at some time instant *t* functions $h_i^j(x^i(\tau), x^j(\tau))$ and $h_i^j(x^j(\tau), x^i(\tau))$ will be set 0 for all $\tau \geq t, t \in [t_0, T]$. In (2) the function $h_i^j(x^i(\tau), x^j(\tau))$ is instantaneous gain that player *i* can obtain through network links with player $j \in K(i)$ (note that $(i, i) \notin P$) where $x^i(\tau), x^j(\tau)$ is the solution of (1).

Define the value of the characteristic function for coalition *N* in the network *G*.

$$V_G(x_0, T - t_0; N) = \max_{u_i,\ i \in N} \sum_{i \in N} \sum_{j \in K(i)} \int_{t0}^{T} h_i^j \left(x^i(\tau), x^j(\tau)\right) d\tau$$

$$= \sum_{i \in N} \sum_{j \in K(i)} \int_{t0}^{T} h_i^j \left(x^{-i}(\tau), x^{-j}(\tau)\right) d\tau$$

where maximum is taken over the set of all admissible controls (see (1)).

Denote by $V(x_0, T - t_0; N) = \max_{G} V_G(x_0, T - t_0; N) = V_{\bar{G}}(x_0, T - t_0; N)$.

Note that the value of $V_G(x_0, T - t_0; N)$ depends on the network that was formed at the initial time instant t_0 as a result of simultaneous selection of neighbors by players. We assumed that players choose such a network $\bar{G}$, which gives the maximum total payoff of players from the set N, i.e. $V_{\bar{G}}(x_0, T - t_0; N)$. We will call such network $\bar{G}$ *a cooperative network or a cooperative interaction network.*

In this setting we suppose that players can change the network structure once during the game process. To find the best time instant for changing the network the Bellmann-type equation is derived. The optimality of corresponding behavior is proved and the example showing the optimal cooperative behavior of players including the one shot network transformation is presented.

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Additional Support in Payment Schemes: Solution to Budget Violations in Finitely Repeated Prisoner's Dilemma

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Abstract. This work examines a finitely repeated prisoner's dilemma with symmetric players and payoff discounting. The research focuses on the problem of implementing a cooperative outcome through payment schemes that satisfy the standard requirements of individual rationality and stability against individual deviations. It is known that for minimal acceptable payment schemes, their feasibility conditions can be violated at individual stages of the game given a fixed (known) duration of punishment for deviations.

We propose an extension of the feasibility concept, based on introducing external support in the form of borrowing from a third party. A class of payment schemes with possible support is formalized, allowing for the temporary attraction of funds with subsequent repayment by the end of the game. The concept of ε-feasibility is introduced, enabling control over local violations of the stage budget constraint.

An explicit cooperation support scheme is constructed, which minimally compensates for the feasibility violation while being almost balanced. It is shown that implementing such support allows for the restoration of the payment scheme's feasibility with practically no loss of efficiency (allowing for the possible collection of a fee for using the third party's resources) and incentive properties. The obtained results demonstrate that the feasibility constraint in finitely repeated games can be overcome through the intertemporal reallocation of resources.

Mathematical Methods for Scheduling in Discrete Manufacturing

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Abstract. This paper considers scheduling problems arising in the operational planning of discrete manufacturing. We study a class of problems to determine the order of processing jobs on limited production resources, subject to release times and due dates.

Let $J = \{1, \ldots, n\}$ be a set of jobs. For each job $j \in J$, the release time r_j, due date d_j, and processing time p_j are given. We denote by C_j the completion time of job j. The objective is to minimize the maximum penalty for late job completion:

$$\varphi_{\max} = \min_{\pi} \max_{j \in J} f(C_j - d_j),$$

where $f(\cdot)$ is a non-decreasing penalty function, and π denotes the schedule under consideration. This problem is a generalization of well-known scheduling theory problems of the type $1 \mid r_j \mid L_{max}$ and $1 \mid r_j \mid T_{max}$, and belongs to the class of NP-hard optimization problems.

To solve this problem, a two-level method is proposed. At the upper level, the job processing sequence is determined. An algorithm based on the branch-and-bound method is developed. A key element of the proposed approach is the use of dual bounds of the objective function, which provide efficient lower bounds on the $\varphi_{\max}$ criterion and significantly reduce the search space.

To obtain lower bounds, we consider a related dual problem, formulated by modifying the parameters of the original problem under a fixed schedule. Dual bounds yields a priori bounds, accelerating the branch-and-bound procedure.

At the lower level, a detailed schedule of operations on machines is constructed. A mathematical model of continuous-time scheduling is proposed, taking into account processing routes, resource constraints, and the possibility of parallel processing of operations. The developed algorithms allow for real-world production features, such as work in progress and the need for rapid rescheduling. The analysis shows that dual bounds significantly reduce explored branches, improving method efficiency. The obtained results can be used in the development of intelligent decision support systems for the operational management of production processes, as well as in the integration of optimization planning methods into corporate information systems of enterprises.

The impact of matrix graph topology on conjugate gradient convergence

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Abstract. Typically, the convergence analysis of the Conjugate Gradient (CG) method – estimating convergence rates, residual norms, and error behavior – relies on spectral properties of the system matrix, such as its condition number and the distribution of its eigenvalues. In this approach, the matrix is treated as a linear operator. This perspective is exemplified in [1], where the convergence analysis of CG is reduced to studying systems with diagonal matrices, which suffices when only spectral characteristics of the matrix are taken into account.

When using topological parameters of the sparse matrix, we consider properties of the graph defined by the matrix. It is well known that in CG, information propagation – i.e., the update of components of recursively computed approximate solution, residual and search direction vectors – occurs along the edges of the matrix graph. Until information has fully propagated across the entire graph, CG convergence cannot be achieved. However, to the best of our knowledge, the impact of rounding error propagation – governed by the same graph structure – on CG convergence has not been previously addressed.

The topological properties of the matrix fundamentally affect the rate at which rounding errors accumulate during CG iterations. Both analytically and experimentally, we demonstrate that for matrices with a small graph diameter, the peak level of rounding error accumulation is reached orders of magnitude faster than for matrices with a large diameter. Consequently, for matrices with a smaller diameter, stagnation in convergence occurs earlier, and the magnitude of true residuals is orders of magnitude larger.

Considering the topological properties of the matrix allows us, in particular, to assess the suitability of different floating-point formats for computations involving that matrix when employing a mixed-precision approach. Even for matrices with significantly worse conditioning but a large graph diameter, we can perform more CG iterations using lower-precision floating-point numbers than for matrices with a small diameter, preserving the required accuracy and increasing computational speed.

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How likely is it to obtain a "mean" solution when solving graph optimization problems with inaccurately specified edge weights?

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Abstract. The coefficients of the objective function in a practical graph-based optimization problem are typically derived from processed measurements, which are almost always subject to errors. In accordance with the least-squares method, the standard estimate for a measured value is usually taken as the mean of all available measurements. By the mean optimal and approximate solutions, we refer to those ones that obtained for the midpoints of the intervals of possible weight values. A *scenario* is defined as a particular combination of the values drawn from their uncertainty intervals. The *probability of an optimal solution* is understood as the probability of obtaining a scenario under which this solution is optimal. The *probability of an approximate solution* with prescribed approximation guarantee is defined similarly. We focus on solutions produced by a greedy algorithm. In this context, the probability of a *greedy* solution is the probability of a scenario that leads the algorithm to output the solution. Assuming some distribution defined over intervals of possible weights, using *the interval greedy algorithm* [1], we obtain all possible greedy solutions, compute their probabilities and the distribution induced on the set of attainable objective function values.

Experiments on a large sample of small-scale set cover problems show that, the probabilities of greedy solutions are surprisingly low – even for modest problem sizes and even when the relative error is small because, typically, the number of possible solutions becomes large. The fraction of problems for which these probabilities are significant decreases as the problem dimensionality grows. The objective function values for *approximate* solutions can differ significantly for different scenarios – both from the value achieved by the solution based on mean weights and from the average objective value over all admissible scenarios.

For mean *optimal* solutions, the situation is considerably more optimistic – as confirmed both by simulation studies for the set cover problem and by exact computations for the minimum spanning tree problem.

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On word-representability of grid graphs[1]

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Abstract. The representation number of a graph is the smallest integer k such that the graph can be represented by a word in which each vertex appears exactly k times, and two distinct vertices x and y alternate in the word if and only if they are adjacent in the graph [1].
In this paper, we prove that m×n grid graphs and m×n cylindrical grid graphs have representation number 3 for $m \geq 3$ and $m \geq 2$, respectively, and $n \geq 3$. Also we extend known results on the representation number for various graph classes to chessboard graphs – namely, king's, queen's, rook's, bishop's, and knight's graphs. We provide a complete classification for queen's graphs and partial classifications or observations for the other classes. This work also leads to several interesting open problems, including representation of toroidal grid graphs.

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Resource management problem with different reproduction and exploitation regimes

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Abstract. A dynamic resource management problem with different reproduction and exploitation regimes is considered. The planning horizon is assumed to be divided into intervals where the resource evolves differently. The optimal control problems with finite and infinite planning horizon are investigated. To maintain the sustainable nature resource evolution the moratorium for exploitation is implemented when the resource grows less. Nonocooperative and cooperative behavior for game-theoretic setting of the problem with infinite planning horizon and interchanging reproduction and exploitation regimes is obtained. The results of numerical modeling are presented.

Comparison of adaptive strategies in infinitely repeated Prisoner's Dilemma

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Abstract. This paper studies an infinitely repeated Prisoner's Dilemma game when payoff functions are defined in two different ways, which can significantly influence the players' choice of strategies. In the first version, the significance of the stage decreases with increase of its number, while in the second version, all stages have an equal impact on the payoffs. The first player uses adaptive strategies studying the opponent's behavior and, based on this information, selects actions at a given stage. This player aims in maximizing the payoff and additionally identifying the opponent's strategy. The machine learning methods are used to describe two adaptive strategies of the first player. One adaptive strategy is based on Bayesian updating, and the other uses the Q-learning method. The strengths and weaknesses of both methods for different payoff functions are provided, along with the criteria for assessing the correct identification of the opponent's strategy. The numerical examples of applying these strategies against strategies known from the literature are given.

A Mathematical Model of Consumer Loan Duration under Early Repayment

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Abstract. We present a mathematical model for credit debt repayment by a representative rational household. The household borrows a consumer loan to increase its current consumption. After taking out a consumer loan, the household chooses a debt repayment strategy that maximizes discounted consumption. The household's objective is to maximize a utility functional comprising two components: the first represents utility derived during the debt repayment period, and the second captures the expected utility from economic preferences after the loan is fully repaid. The model is formalized as an optimal control problem featuring a non-compact control set and an endogenous time horizon. The necessary optimality conditions in the form of the Pontryagin maximum principle are investigated. We provide an analysis of the post-repayment utility functional and study the duration of the early debt repayment regime.

Variational-Operator Formulation of Training and Proximal Kernels for Verifiable Intelligent Systems[1]

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Abstract. The work presents an approach to training deep models where the data processing sequence is identified with finding an equilibrium state in a dynamical system. Instead of the traditional sequential pass through neural network layers, we propose a variational-operator approach, in which the model output is defined as a solution to a monotonic inclusion under given constraints. In this formulation, the process of reaching information equilibrium is equivalent to solving a variational inequality. This allows us to treat neural network structures not as rigid computational graphs, but as operator equations that remain invariant to the smoothness of activation functions.

The computational framework is built upon proximal mappings, which provide a unified description for both nonlinear activation functions and various forms of regularization. The use of proximal operators allows the behavior of non-smooth activations (such as ReLU) to be reduced to complementarity problems. This interpretation resolves the gradient uncertainty issue at kink points and enables the use of optimization methods to find activations directly, bypassing classical backpropagation.

The practical significance of this method lies in the ability to implement iterative procedures without constructing an automatic differentiation graph. Eliminating the need to store intermediate activations in GPU memory significantly reduces hardware requirements and simplifies the reproducibility of results. Particular attention is paid to the mathematical verifiability of the system: the stability and uniqueness of the solution are guaranteed by the operator's properties, specifically its strong monotonicity. To confirm reliability, we propose a statistical testing protocol that moves away from selecting a single "best run", instead relying on the analysis of trajectory convergence across diverse initial conditions.

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Regularized PINN for epidemic forecasting

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Abstract. Physics-Informed Neural Networks (PINNs) provide a flexible framework for solving forward and inverse problems governed by differential equations by embedding physical constraints directly into the training objective [1]. In recent years, this approach has attracted significant attention in epidemic modeling and forecasting, where reliable estimation of epidemiological parameters is critical for informed decision-making, public health planning, and risk assessment under limited and uncertain data conditions [2].

In this study, we apply PINNs to epidemic forecasting using the classical SIR (Susceptible-Infected-Recovered) model, focusing on the inverse problem of identifying unknown epidemiological parameters from sparse and potentially noisy observations. A known challenge in training PINNs for inverse problems is the imbalance between different loss components, including governing equation residuals, initial condition constraints, and data mismatch terms. In epidemiological models, such imbalance can lead to poor enforcement of initial conditions, non-physical solutions, and inaccurate reconstruction of state trajectories, even when the inferred parameters appear plausible [3].

To address these issues, we propose a regularized PINN formulation incorporating several complementary strategies. First, normalization of both the temporal domain and state variables is applied to reduce scale disparities between loss components and to improve gradient propagation during training. Second, weighted loss balancing is introduced by assigning distinct weights to the differential equation residuals, initial condition constraints, and data-driven terms, enabling explicit control over the contribution of each physical requirement.

The resulting loss function combines residuals of the governing equations enforced at collocation points, penalties for violations of initial conditions, and mismatch terms corresponding to sparse observational data. A hybrid optimization strategy combining Adam and L-BFGS optimizers is employed to ensure stable convergence and accurate enforcement of the physical constraints, following common practice in PINN-based inverse problems [1].

A systematic analysis of different weighting strategies reveals that excessive emphasis on data fidelity may deteriorate physical consistency, while overly strong enforcement of differential constraints can hinder accurate parameter identification. Numerical experiments on synthetic epidemic data demonstrate that the proposed regularized PINN formulation improves training stability, promotes physically meaningful solutions, and reduces sensitivity to observational noise.

The presented results highlight the importance of normalization and regularization in PINN-based inverse epidemic modeling. In future work, the proposed approach can be extended to scenarios with stronger noise levels, partial observability, and more complex compartmental models.

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Preference discovery in large centralized higher education market with two-tier admission: the role of student beliefs

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Abstract. Many education markets are centralized where a clearing-house matches the university seat capacities with student preferences and abilities. The Gale-Shapley deferred acceptance mechanism is a widely adopted mechanism (Fack et al. 2019) where the students dominant strategy is to truthfully report their preferences. But both lab and field experiments detect that students misrepresent their preferences (Rees-Jones and Shorrer 2023), e.g., suboptimal behavior emerges from the complexity of the process, due to the strategically demanding mechanism (Hassidim et al. 2021), or when students face only limited uncertainty about their admission outcomes (Fack et al. 2019). This study uses the HSE monitoring dataset on the unviersity enrollment in Russia from 2011 to 2023. Since the Unified State Examination (USE) became mandatory, the system of centralized choice has been experiencing changes: from the mechanism of three-round allocations to the one-round allocation with the university-specific ranking since 2025, government-run nation-wide consolidation of universities since 2013, and proposed reductions in paid-tuition places. The student preference model can offer guidance to this many policies and estimate the influence of student beliefs on the stability of the large centralized market. This study expands empirical research (Agarwal and Somaini 2018; Fack et al. 2019; Arslan 2021) by modeling student behavior using conditional probability model, by introducing the two-tier admission system, where admission contest runs successively for free and paid tuition, and by introducing the hierarchy of national, regional, and local educational alternatives. We assume that student choice is influenced by his true preferences and his belief about the chance of being admitted to a university program. The subjective admission probability is estimated using the bootstrap approach with the previous year admission data. Student true preferences follow a random linear utility model and inference is done using discrete choice model with individual-specific choice sets. We run cross validation, at first, estimating only the choice of the program; then, we estimate the composite choice of university and program. The stability of the observed student allocation in the selected model is compared with the case of perfect foresight assuming that the students know their (ex-post) choice sets (Fack et al. 2019).

Rearrangement Methods for the Two-Dimensional Bin Packing Problem

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Abstract. This study addresses the two-dimensional irregular bin packing problem under discrete rotations of 90°, 180°, and 270°. The objective is to minimize the number of used containers while maximizing the unused area in the last bin.

We propose local rearrangement strategies to improve an initial feasible packing through destruction and algorithmic reconstruction. The procedure begins with an operator that removes a subset of centrally located objects from the least-filled bin (excluding the last bin). Then, the geometric contact-driven sliding procedure shifts objects to their maximal feasible positions in the bin. The removed objects are then repacked together with items from the remaining bins, processing the bins sequentially. In addition, objects from the last bin are also considered for repacking at this stage. During this process, selected containers are unpacked and reconstructed to improve the overall packing. The procedure is iteratively repeated until no further improvements can be achieved. Computational experiments for the proposed local rearrangement strategies on real-world and well-known datasets are presented.

Experimental Evaluation of Pairwise Similarity Heuristics for the Majority Domination Problem

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Abstract. The majority domination problem occurs in two-tier voting systems, where agents vote in local neighborhoods and group results de- termine a final outcome. Given a graph with loops and vertices, each vertex has an opinion −1 and 1; a vertex will vote "yes" if the sum of the opinions in its neighborhood is positive, and a proposal will be accepted if a majority of the vertices vote "yes". The goal is to find the minimum number of supporting agents needed for acceptance. This problem is NP-complete on general graphs; however, there are polynomial-time solutions for trees, co-graphs, and k-graphs. Analytic solutions are also known for odd-regular graphs. To solve arbitrary graphs, a pairwise comparison approach was previously proposed that uses structural comparisons and heuristics to provide accuracy guarantees for tree, complete graph, and odd-regular graph solutions. In this paper, we present the first comprehensive experimental evaluation of these methods. We implemented three structure-based methods and compared them to an exact mixed integer linear programming (MIP) formulation and other metaheuristic approaches. Experiments were conducted on Erdos-Renyi graphs, nearcomplete and nearregular graphs, as well as adversarial examples to evaluate solution quality, feasibility and computational time.

Thermal Power Plant Maintenance Scheduling

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Abstract. This research addresses the Generation Maintenance Scheduling problem in the context of thermal power plants. The primary business objective is to maximize profitability by scheduling preventive maintenance overhauls, while ensuring that demand is met and grid stability is maintained. This requires navigating a complex landscape of industrial constraints. For instance, to guarantee sufficient operational time between overhauls, strict inter-repair resource limits are enforced. Furthermore, dependencies between linked generating units mean that taking one unit offline can temporarily disable an entire group. During peak demand periods, the scheduler must ensure that equipment groups can meet minimum daily production targets to uphold system reliability.
Industrial application has planning horizon of up to five years, encompassing up to 1,000 individual generating units, and considering up to 10 distinct maintenance types. In this context, this GMS problem shares structural similarities with the Job Shop Scheduling Problem and the Resource-Constrained Project Scheduling Problem but is further complicated by the aforementioned cascading unit dependencies and strict business rules on group production targets. Recent comprehensive reviews highlight the growing research interest in this area, such as the work by Beemsterboer et al. [1], which provides an overview of integrated production and maintenance scheduling, and the study by Nikoobakht et al. [2], which examines maintenance strategies in modern power systems. To overcome NP-hard nature of the problem, we discuss the application of a hybrid solution approach using MIP, heuristics, and constraint propagation techniques within an iterative decomposition framework. Numerical experiments are presented.

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Self-adaptation of genetic algorithm parameters on pseudo-Boolean optimization problems

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Abstract. Both theoretical and practical studies of genetic algorithms (Gas) indicate that the choice of population size and mutation parameters is often a non-trivial task, requiring costly experimental tuning or deep understanding of the problem structure [1, 2]. As demonstrated in [3], selecting the mutation rate for multimodal pseudo-Boolean fitness functions is significantly more challenging than for unimodal ones.

In this work, we consider two families of problems with fundamentally different fitness functions: the Jump function [5], which features a plateau of local optima, and the Funnel function [6], which has a single local optimum with an extensive basin of attraction. We show that fixed parameters that are efficient for one problem lead to failure on the other, and no universal static configuration exists.

We consider a self-adaptation mechanism in which the population size and mutation intensity are controlled based on the population diversity index proposed in [4]. We propose a new variant of this diversity measure that additionally incorporates the Hamming distance between individuals, combining fitness and genotypic diversity.

Experimental results demonstrate that the adaptive variants yield robust performance across both problem families, whereas none of the considered fixed parameters of the classical algorithm is universal.

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On the Facets of the Vehicle Routing Problem Polytope

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Abstract. We consider the problem of constructing a family of several simple cycles (m-tour) in a complete edge-weighted graph. The total cycles weight is minimized. All cycles intersect at a single vertex of the complete graph; the cycles have no other intersections. We study the polytope of the m-tour family. We found the affine hull of the m-tour polytope, and show that the constraints of the unit cube generate its facets. We also study clique inequalities with respect to the m-tour family. Their ranks and conditions of thier facetness are obtained. For the problem of minimizing the weight of an m-tour a cutting plane procedure using clique facets is developed. A computational experiment is conducted.

A new integer model for the problem of single-jobs servicing with precedence by parallel machines

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Abstract. The problem of scheduling the servicing of a partially ordered set of jobs with unit service duration by parallel identical machines is considered. Previously, an integer linear programming model was proposed for this problem; however, the coefficients in the objective function exhibited exponential growth. This made it difficult to apply the model to large-scale problems. In the present work a new integer linear programming model is described, in which the introduction of additional variables allowed avoiding the growth of coefficients in the objective function. A comparative analysis of the models is conducted, and computational experiment is present, in which random acyclic directed graphs were used.

Second-Order Complexity of Minimax Optimization with Lazy Hessian Updates Complete Analysis of the Minimax-AIPE with LEN Framework

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Abstract. We consider the convex-concave minimax problem $\min_{x\in X}\max_{y\in Y} f(x,y)$ over compact sets withρ-Lipschitz Hessian and study its second-order oracle complexity. Previous algorithms based on Newton Proximal Extra-gradient [1] require $O(\varepsilon^{-2/3})$ Hessian evaluations, a bound long believed to be optimal; Chen et al. [3] recently refuted this conjecture by proposing the Minimax-AIPE algorithm, a triple-loop Catalyst-type acceleration framework that achieves $\tilde{O}(\varepsilon^{-4/7})$ second-order oracle complexity. The same work further asserted, citing [2] without detailed proof, that replacing the inner subroutine with Lazy Extra Newton reduces the Hessian query count to $\tilde{O}(m+m^{5/7}(D_x^3\rho/\varepsilon)^{2/7}(D_y^3\rho/\varepsilon)^{2/7})$ when the Hessian is reused every m steps. In this work we provide a complete and self-contained proof of this claim, establishing the key lemmas on block-motion control and energy monotonicity under stale Hessians, and showing that the parameter choices $\gamma=\rho/\sqrt{m}$ and $\gamma_H \geq 4m\rho$ are necessary and sufficient to guarantee convergence within the minimax acceleration framework.

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Generalized Trash Compaction is NP-complete

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Abstract. There are numerous variations of puzzles that can be played on a grid with movable blocks that can be pushed according to different local rules. Typically, the central algorithmic question is: "Can we reach a given configuration starting from another one?" One such game, Trash Compaction, is known to be NP-hard. Its NP membership was not shown explicitly and is nontrivial, since, due to the non-commutativity of the operations, a straightforward solution may have exponential size and therefore cannot be verified directly. Moreover, some similar problems are known to be PSPACE-complete, for example, Rush Hour puzzle. In this paper, we introduce a natural generalization of Trash Compaction by changing the main objective of the game and show that the resulting decision problem is NP-complete by explicitly presenting a certificate and establishing its correctness. Another interesting fact is that, in the course of analyzing the internal structure of our problem, Young diagrams naturally emerge, indicating a nontrivial connection to algebraic combinatorics and representation theory. Moreover, we present several structural and algorithmic observations about this model that may be useful for further research. Finally, we formulate a hypothesis about the model that remains open, and we provide some partial progress towards it.

On Global Optimality Conditions for an Epidemic Optimal Control Problem[1]

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Abstract. We address an Optimal Control (OC) Problem with a state-nonlinear control system (CS) and a terminal cost functional given by a convex function, so that the nonconvexity of the OC Problem is produced only by a specific state-nonlinear CS. First, the OC Problem is reduced to a variational problem without constraints with the help of the Exact Penalization Theory and usual penalty function.
Further, we construct an estimation of the classical penalty function with the help of a special form of CS, given by state-nonlinear system of ODE's with the state-DC functions. Using the DC-decomposition of the DC-data, we proposed the Global Optimality Conditions (GOCs) of necessary and sufficient form for this kind of nonconvexity. The GOCs possesses the "constructive property": if the "principle inequality" of GOCs is violated, then there is a possibility to improve the control under scrutiny and to get a better value of the cost functional. It allows not only to ameliorate stationary controls (i.e. satisfying the PMP), but to construct numerical method for nonconvex OC Problem.

[1] The research is carried on with support of RSF, project № 24-41-03004, http://rscf.ru/project/24-41-03004/.

On Local Search in Epidemic Optimal Control Problems[1]

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Abstract. We address a state nonlinear control systems (CS) of very popular form in the epidemic modeling area with the terminal cost function defined by a convex function, so that the nonconvexity of the Optimal Control (OC) Problem is produced only by specific state nonlinear CS.
With the help of an usual penalty functional, the OC Problem is reduced to a variational problem without constraints. Further, using a special form of control system given by system of ODE's, where the right-hand part is given by state-DC functions, we obtained a upper estimation of the initial penalty functional by means of two functional, one of which generate a state-linear control system, while the second one is represented as a difference of two state-convex functional (state-DC functional). Furthermore, applying the scheme of partial linearization, with respect to the basic non-convexity of so constructed state-DC OC problem we develop a local search (LS) scheme, by employing idea of consecutive solving the state-convex OC Problems. Finally we investigate the convergency properties of developed LS Scheme.

[1] The research is carried on with support of RSF, project № 24-41-03004, http://rscf.ru/project/24-41-03004/.

Heuristics for the Maximum-Weight Minimal Dominating Set Problem

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Abstract. We consider the problem of finding a minimal-by-inclusion set that is dominating and that is generating a maximum-weight cut in an edge-weighted graph. A number of heuristic procedures are used to solve the problem: local search, simulated annealing, the bee swarm algorithm, and the ant colony algorithm. These heuristics are compared on a series of randomly generated examples. To obtain statistical estimates of the accuracy of the developed procedures, exact solutions are preliminarily found for a number of examples.

Impact of different types of target functions on rational strategies for economic development

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Abstract. We consider two approaches to modelling the dynamics of income distribution for reproduction and consumption based on the Solow equation. One of the approaches is used in the recently proposed model [1]. The novelty lies in the fact that the subject's welfare level exceeds a fixed value during the whole period under consideration, and also in the fact that the control criterion is the minimisation of effort to achieve a given constraint on the welfare level.
The second approach is used in the simplified Ramsey model [2]. In it, the maximised functional is the "integral specific consumption".
Some numerical calculations using the new approach were conducted and, unexpectedly, it was revealed that in the considered examples of medium-term forecasting, the value of "integral specific consumption" is higher than the value obtained with the simplified Ramsey model with the same values of parameters.
The aim of this report is to investigate in detail the influence of different types of target functions and different intervals of values of other parameters of mathematical models of growth of the economy on rational strategies of its development.

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Stable Cooperation in Differential Games on Hypergraphs

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Abstract. This study examines a cooperative differential game on a hypergraph. Hypergraphs offer powerful tools for modeling complex structures and relationships across diverse domains, particularly many-to-many social interactions. However, their intricate structure necessitates novel approaches to constructing cooperative solutions. A specialized characteristic function accounting for the game's network structure is introduced, and its properties are analyzed. Using this construction method, the game's core is shown to be nonempty and strongly time-consistent. The Shapley value and the τ-value are also investigated as optimality principles. The results are illustrated through a numerical example.

Lower Bounds for the Virtual Machine Allocation Problem with Affinity Constraints at the Subnetwork Level[1]

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Abstract. We consider the virtual machine (VM) allocation problem in a cloud data center on NUMA-based servers with additional constraints ensuring low communication latency within subnetworks.

Each VM has an arrival time, a finish time, and a type that specifies CPU and memory requirements for allocation. A potentially unlimited number of subnetworks is available; each subnetwork contains the same number of homogeneous servers, and each server has a given number of NUMA nodes with specified resource capacities. Some VMs consist of multiple components that must be placed on the same server but on distinct NUMA nodes. Subsets of VMs may form placement groups, in which case all VMs in a group must be allocated to the same subnetwork. The objective is to allocate all VMs over the planning horizon while lexicographically minimizing first the number of active subnetworks and then the number of active servers, subject to all constraints.

We propose an approach to construct lower bounds on the minimum number of active subnetworks, the minimum index of the last active server, and other related bounds on the objective. The method is based on the combined use of the Benders decomposition and column generation approach.

To evaluate the proposed approach, we constructed a synthetic dataset comprising instances of varying size and structural complexity. Based on this dataset, we conducted computational experiments to assess the quality of the derived lower bounds. The obtained bounds are compared with known bounds for the relaxed problem and demonstrate a notable improvement in tightness.

[1] The research was supported by Russian Science Foundation grant № 22-71-10015-П, https://rscf.ru/en/project/22-71-10015-П.

Dynamic Competitive Facility Location Problem with unknown consumer budgets

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Abstract. We consider a Dynamic Competitive Facility Location Problem with unknown consumer budgets, formalized as a sequence of Stackelberg games over a finite planning horizon. At each time interval, the Leader solves a bilevel problem, determining the set of facilities to be opened and assigning them to consumers. Unlike the classical formulation, consumer budgets are unknown; the parties know only the bounds of possible values, and the Leader's revenue estimates may not coincide with either the true values or the Follower's estimates. After each step, information about the captured consumers budgets is refined (revealing individual budgets).

The Leader's strategies are determined by the choice of consumer budget estimates, as well as by the Follower's estimates of consumer budgets. The impact of the Leader's strategy choice on the placement structure, profits, and market redistribution dynamics is studied. Modeling was carried out for various strategies and scenarios for information clarification.

Large-scale multi-criteria Airline Crew Recovery problem: partial pairing reassembly and adaptive hierarchical optimization

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Abstract. In airline crew scheduling, a pairing is a multi-day sequence of flights that begins and ends at a crew base. It comprises the specific flight legs, connections, and overnight layovers a crew works before returning home. A crew schedule, by contrast, is a personalized monthly timetable constructed from a combination of these pairings, interspersed with days off, reserve duty, training, and other activities. It defines the complete work-life plan for an individual crew member over a month-long bidding period. Airline crew schedules are frequently disrupted by external factors, changes in employee or aircraft status, and internal operational processes (disruptions cause the breakdown of pairings, which forces planners to repair the overall monthly crew schedules). From an operational time interval until month-end, airline recovery involves a sequence of actions to adjust and repair crew schedules. These actions are required due to the daily accumulations of plan changes and solution degradation. This recovery process comprises a series of problems to be solved within soft time limits, where pairings recovery precedes crew assignment.

This study proposes solution methods utilizing mathematical heuristics to identify improved solutions for large-scale airline recovery problems, specifically the crew split problem and the airline crew scheduling problem. The objective is to construct schedule which meet business requirements with minimum deviation from original one. Our proposed solution process enables parameter tuning to balance solution space reduction with available computation time, and introduces methods for effectively navigating the trade-off between solution quality and runtime. By integrating scheduling and pairing decisions, our method accommodates larger deviations from the original timetable while maintaining safe crew working periods.

Computational studies are conducted using actual flight and crew schedules from major Russian airlines across various fleet types. The problem encompasses five distinct fleets, each varying significantly in size. A single fleet may contain between 250 and 6,000 available crew members and must cover between 500 and 9,000 operational pairings. The primary optimization criterion minimizes costs associated with crew disruptions while satisfying constraints, including flight time, work time and rest limitations.

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Optimal control and investment opportunities for “Power to Gas” energy storages

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Abstract. This work continues our research into optimal control strategies and return on investment for different types of storage devices in different electricity markets. In contrast to the previous studies [1, 2], we consider energy storage devices with low round trip efficiency coefficients, such as hydrogen energy storages. For them, the efficiency of the cycle “loading energy from the grid – unloading energy from the storage device back into the grid” is currently 35-50% (see [3]). For daily electricity tariffs corresponding to the Russian market, optimal control in this case differs significantly from that found previously for other types of storage devices (lithium-ion, lead-acid, etc., see [1]). Next, the net present value (NPV) for investing in an energy storage device is determined, taking into account equipment wear, reinvestment of profits in increasing capacity, and the dependence of profits and the cost of increasing capacity on the volume of the storage device. Based on previously obtained results [1], the optimal value of the storage capacity per unit of power and the corresponding profit are calculated depending on the parameters of the tariff and the storage device. Despite the mentioned drawback, the investment return for hydrogen energy storages is positive and expected to increase significantly by 2030 due to reduced capital costs and improvements in other parameters. As a result, the growth rate of NPV when reinvesting profits into capacity reaches 15% per year. Similar calculations are performed for other established energy storage technologies (pumped hydroelectric power plants, flywheel storage systems). The resulting values confirm the high investment potential of hydrogen storage systems in the medium-term prospect.

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An Integer Linear Programming Model for Combined Register Allocation and Instruction Scheduling

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Abstract. We consider the combined problem of register allocation and instruction scheduling. It remains one of the most challenging optimization problems in modern compiler design, as the sequential handling of these interdependent phases often leads to suboptimal performance due to the phase-ordering problem. To address this, we have developed a unified mathematical model based on integer linear programming that simultaneously captures instruction dependencies, resource constraints, and register live ranges.

The formulation encodes the exact trade-offs between preserving values in registers and inserting spill code, which in turn affects the critical path length of the computation. By combining these aspects, the model is able to make optimal decisions about, for instance, whether it is beneficial to spill a register to reduce memory traffic. Based on this model, we have developed a matheuristic that aimed at minimizing the length of the final schedule. The main difficulty of this approach is to obtain good lower and upper bounds, given the complexity of exact optimization for large instruction blocks. To estimate the optimality gap, we proposed a combination of techniques: deriving lower bounds through linear relaxations of the ILP formulation, computing theoretical lower bounds based on graph-theoretic properties.

Experimental results show that the proposed method consistently produces schedules with small optimality gaps relative to the theoretical lower bounds. These findings suggest that the proposed approach can provide a reliable benchmark for evaluating heuristic algorithms and also offer a foundation for developing hybrid approaches.

Greedy algorithms for finding upper bounds on the temporal bin packing problem with failure domains

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Abstract. For systems related to cloud computing, the most relevant task is to find an efficient resource allocation. One of the problems arising in the search for allocation is the installation of virtual machines on servers, minimizing their number. This problem is a complicated version of the classical bin packing problem, because in this case we consider groups of virtual machines that must be placed in accordance with certain rules – they must work in independent domain zones. For this problem we developed an algorithm for finding the upper bound. We used an approach in which we considered two agents – a server and a virtual machine. For each of the agents, we defined several strategies for determining the preference of the second agent. Each strategy is given some set of parameters for the algorithm. A set of hyper parameters was produced and the most appropriate strategy was identified.

Frank-Wolfe Algorithms for (L_0, L_1)-smooth functions

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Abstract. We propose a new version of the Frank-Wolfe method, called the (L_0, L_1)-*Frank-Wolfe* algorithm, developed for optimization problems with (L_0, L_1)-smooth objectives. We establish that this algorithm achieves superior theoretical convergence rates compared to the classical Frank-Wolfe method. In addition, we introduce a novel adaptive procedure, termed the *Adaptive* (L_0, L_1)-*Frank-Wolfe* algorithm, which dynamically adjusts the smoothness parameters to further improve performance and stability. Comprehensive numerical experiments [1] confirm the theoretical results and demonstrate the clear practical advantages of both proposed algorithms over existing Frank-Wolfe variants.

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Opinion dynamics and mutual influence with LLM agents through dialog simulation

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Abstract. A fundamental challenge in opinion dynamics research is the scarcity of real-world longitudinal opinion data, which complicates the validation of theoretical models. To address this, we propose a novel simulation framework using large language model (LLM) agents in structured multi-round dialogs. Each agent's dialog history is iteratively updated with its own previously stated opinions and those of others analogous to the classical DeGroot model. Furthermore, by retaining each agent's initial opinion throughout the dialog, we simulate anchoring effects consistent with the Friedkin-Johnsen model of opinion dynamics. Our framework thus bridges classical opinion dynamics models and modern multi-agent LLM systems, providing a scalable tool for simulating and analyzing opinion formation when real-world data is limited or inaccessible.

A Multi-Agent Approach to Large-Scale Delivery Scheduling

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Abstract. We consider a large-scale delivery system scheduling problem in which sites are grouped into clusters and assigned to monthly time periods, each requiring a specific start day. The problem is related to the resource-constrained multi-project scheduling problem (RCMPSP), but features domain-specific structure including material transport across multiple warehouses, contractor capacity with time windows, cluster activation thresholds, and plan adherence constraints. The objective is to maximize the number of completed sites. Sites that cannot be feasibly scheduled may be deferred.

We propose a hierarchical decomposition into five cooperating agents: cluster division, cluster planning, site scheduling, material management, and contractor assignment. Upper-level decisions (cluster-to-month assignment) frame subproblems for lower-level agents (site-to-day scheduling), and resource feasibility is enforced by dedicated material and contractor agents. Both levels are solved by Large Neighborhood Search (LNS) with destroy and greedy earliest-feasible-date repair operators. The modular design allows each agent to be independently modified or parallelized, making the system adaptable to diverse problem variants. To improve the cluster division agent, we develop a surrogate model that approximates the cluster activation constraints with an explicit optimization formulation, removing the need for expensive feasibility checks when partitioning sites into clusters. The surrogate is verified on a threshold-type activation case.

Computational experiments on large-scale instances with thousands of clusters and tens of thousands of sites show that the hierarchical LNS matches MIP optima on tractable instances while being orders of magnitude faster. General-purpose black-box optimization frameworks either violate problem constraints or complete very few sites, because they cannot exploit the problem structure. In contrast, the proposed method maintains constraint satisfaction through its decomposition design and scales effectively to large instances.

Relaxation Variants of the Proximal Method and the Regularized Proximal Method via Auxiliary Functions Approximation

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Abstract. We propose two methods for solving the convex programming problem. One of them is a variant of the classical proximal method, and the second is a modification of the also well-known regularized proximal method. The proposed methods are characterized by the fact that the sequence of approximations is constructed by them with a relaxation condition. In addition, the methods use the operation of embedding the epigraphs of auxiliary functions into some polyhedral sets in order to simplify the solving problems of constructing iteration points. We discuss implementations of the methods and prove their convergence.

Parallel Evolutionary Algorithm with Optimized Operators for Total Weighted Tardiness Problem on One Machine[1]

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Abstract. An evolutionary algorithm with optimal recombination is proposed for the NP-hard Total Weighted Tardiness Problem on One Machine. Performance of evolutionary algorithms depends on the crossover operator, where the components of parent solutions are combined to build the offspring. *Optimal recombination problem* (ORP) is a subproblem, that consists in finding the best possible offspring as a result of a crossover operator, given a number of feasible parent solutions under the requirement that the recombination should be respectful and gene transmitting as coined by N. Radcliffe (1994).

The optimal recombination problem for scheduling on permutations with the position-based representation of solutions is formulated as follows.

Given parent solutions $\pi^1, \pi^2, \ldots, \pi^m$. It is required to find a permutation π' such that:

(I) $\pi_i' \in \{\pi_i^1, \pi_i^2, \ldots, \pi_i^m\}$ for all $i = 1, \ldots, n$.

(II) π' has the optimum value of objective function among all permutations that satisfy condition (I).

The corresponding recombination operators, where the ORP is solved, are called optimized crossovers. The computational complexity of the ORP is analyzed. We prove NP-hardness in various particular cases with different structure of the initial data. Various algorithms are applied to solve the ORP using parallel computing.

We construct the initial population by means of greedy constructive heuristics. Local search heuristics are used to improve the initial and the final populations. The computational experiment on the OR-Library instances shows that the proposed algorithm yields results competitive to those of well-known algorithms and confirms that the optimal recombination may be used successfully in evolutionary algorithms.

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Evolutionary algorithms for the optimization variant of the graph-subgraph isomorphism problem

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Abstract. The optimization variant of the graph-subgraph isomorphism problem aims to find a mapping between vertices of two graphs that maximizes the number of preserved edges. In this work, evolutionary algorithms are investigated on the stated problem. A (1 + 1) evolutionary strategy with several mutation operators and a genetic algorithm with cycle crossover and tournament selection are proposed. An adaptive operator selection mechanism based on reinforcement learning is introduced to improve the evolutionary strategy. Computational experiments on randomly generated graphs demonstrate the effectiveness of the proposed methods.

Evolutionary strategy for two-side market pricing problem with information distribution on a plane

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Abstract. The report will discuss the search for Nash equilibriumin the pricing problem in a two-sided market with information dissemination on the plane using an evolutionary strategy. An evolutionary strategy is proposed to find the Nash equilibrium. Solutions are encoded by vectors whose elements correspond to the players' strategies. The mutation operator makes random changes to the solution components with a given probability. The selection of individuals for the next generation is carried out using greedy strategies based on the players' gains. An experimental study is conducted on test cases with different input data structures.

TempShapG: Tracking Temporal Feature Importance in Time Series Forecasting

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Abstract. Time series data typically consist of continuously generated observations recorded sequentially over time, reflecting evolving trends and periodic fluctuations of variables. Such data play an important role in machine learning, especially in tasks involving prediction, monitoring, and modelling of dynamic systems. Current mainstream feature importance algorithms typically evaluate importance solely from the perspective of feature dimensions, neglecting how feature importance changes over time. To address this issue, this paper proposes TempShap, a Shapley-value-based method that computes feature importance while tracking its variation across time steps. We further incorporate the graph-based coalition sampling from our previously proposed ShapG method to reduce computational cost. Experiments on multiple time series forecasting models using the Jena climate dataset show that TempShap produces consistent feature importance rankings, validated through progressive feature masking. Furthermore, we observe that cumulative feature importance converges as the number of time steps increases, indicating stable and reliable temporal explanations.

A Branch-and-Cut Algorithm for the Minimum Weight 3-Coloring Problem

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Abstract. This paper addresses the NP-hard problem of coloring the vertices of an edge-weighted undirected graph with 3 colors to minimize the total weight of edges connecting vertices of the same color. This problem is mathematically equivalent to the well-known Max 3-Cut problem, where the objective is to maximize the weight of edges connecting vertices in different parts. While our previous research focused on heuristics, meta-heuristics, and lower bound computations, this work presents an exact algorithm within the Branch-and-Cut framework.

Although existing literature on Max 3-Cut extensively explores various valid inequalities and branching rules, we propose a novel structural decomposition approach aimed at reducing the depth of the branching tree. The core idea relies on identifying a set of boundary vertices (separators) and multiple independent vertex clusters, such that no edges connect vertices from different clusters.

The proposed algorithm prioritizes branching on a subset of k boundary vertices. Once the colors of these k vertices are fixed, the remaining problem is added to the task pool and processed via a two-stage strategy. First, a lower bound is computed using a partial relaxation, in which only the variables corresponding to the boundary vertices are relaxed to continuous values. If this bound is insufficient to prune the branch, the solver proceeds to find the exact integer solution for the sub-problem. Extensive numerical experiments were conducted on real-world graphs, unit-disk graphs, and standard benchmark instances. We compared the performance of the standard SCIP solver against our decomposition-based algorithm. The results demonstrate the high performance of the proposed approach.

Nash Stable Partition in Monotone Games

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Abstract. Let $N = \{1, 2, ..., n\}$ be the set of players and $\Pi(N)$ be the set of all partitions of N. A non-empty subset of N will be called a coalition. *A coalition partition game* is a pair (N, H), where $H : \Pi(N) \to R^n$. The number $H_i(\pi), \pi \in \Pi(N)$, $i \in N$ is the payoff of player i in the coalition partition π. Let $\pi(i)$ be the coalition containing player i in π, that is, $i \in \pi(i) \in \pi$. *A hedonic coalition partition game* is a coalition partition game such that $\forall i \in N$ the payoff of each player depends only on the coalition containing i, that is, $H_i(\pi) = H_i(\pi(i))$.

Definition 1. A coalition partition π^* is called a Nash stable partition with fixed cardinalities up to one *if* $\forall i \in N$

$$H_i(\pi^*) \geq H_i(\pi) \quad \forall \pi \in D_i(\pi^*)$$

with the possible exception of one player $j \in N$. It is denoted $NSPC_1$.

Definition 1 implies that an NSPC is an $NSPC_1$. Let us give some examples. Let $N = \{1, 2, 3\}$ and $|\pi| = 2$. Then in the monotone game (N, H) there exists an $NSPC_1$. Indeed, suppose the contrary, i.e., in every partition of π in $\Pi(N)$ at least two players i in N have $H_i(\pi) < H_i(\rho) \quad \forall \pi \in D_i(\pi)$. Monotonicity implies that $\forall i \in N H_i(i) \geq H_i(\pi) \quad \forall \pi \in D_i(i)$. Therefore, by the proposition, $H_i(\pi) < H_i(\rho) \quad \forall \pi \in D_i(\pi)$ holds for two coalitions. Let's transfer one of these players to the other coalition. This creates a coalition structure of π^*, then $H_i(\pi^*) \geq H_i(\pi) \quad \forall \pi \in D_i(\pi)$ holds. By the assumption that $NSPC_1$ does not exist for the remaining players, the result given in the example follows from Lemma 1.

Lemma 1. *In a monotone game (N, H) there exists* $NSPC_1$.

Definition 2. A hedonic coalition partition game Γ is called monotone if

$$\forall i, j \in \pi(i), i \neq j \quad H_i(\pi(i) \setminus \{j\}) \geq H_i(\pi(i)).$$

Theorem 1. *In monotone hedonic coalition partition games, there is NSPC.*

Ordinal Algorithm (for Two Coalitions). Consider the following transition algorithm:

Step 1. Choose player x in the game and calculate their payoff $\rho_{min} = H_x(B)$ in coalition partition π^*. The algorithm starts with the partition $\pi^* = \{A, B\}$.

Step 2. In each coalition partition, first calculate player x's payoff and determine whether it is profitable for them to switch to the other coalition. If it is profitable for player x to switch to the other coalition and their payoff is strictly greater than ρ_{min}, then, regardless of the wishes of the other players, we transfer player x to the coalition they wish to switch to.

Step 3. If player n wants to switch, but their payoff is ρ_{min}, then consider players b_j, wherever they are. If there is at least one player among them willing to switch, then we switch these players in random order until all players b_j are satisfied. After that, consider all players a_i, wherever they are, and assign them the following switching order. In each coalition partition, we maintain the switching order.

Lemma 2. *Suppose there is no NSPC in a game and* π *is a weak NSPC. Then there exists a weak NSPC* π^{-1} *such that when some player* $i \in \pi^{-1}(i) \in \pi^{-1}$ *moves, a partition of* π *results.*

Lemma 3. *In a monotone coalition partition game there are no unit cycles.*

Properties of Approximation Methods

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Abstract. This paper presents a review of the author's research results on the properties of approximation methods, as presented in the Scientific Report [1] and other publications. It examines octahedral (least absolute deviations), Euclidean (least squares), Hölder, and Chebyshev projections of the origin onto linear manifolds and convex polyhedra (sets of solutions to systems of linear inequalities). Results are presented on the influence of the choice of positive weight coefficients for the vector components of the specified norms on the obtained results. Approximations using asymmetric norms and dual approximation problems are also considered.
An algorithm for Chebyshev approximation that does not require the Haar condition is described, which expands and simplifies the application of Chebyshev approximation. Results establishing connections with other formulations of approximation problems are presented.

References

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Software module for preparing student attestation sheets[1]

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Abstract. The integration of a digital service for the automatic generation of attestation sheets into a university ecosystem is a complex task of aligning data, security requirements, and operational resilience with existing information systems. The service processes personal student data and curricula using OCR technology, semantic matching, and vector databases, so its correct and secure deployment is critical for practical use.

The study focuses on identifying the key considerations for integrating the service with a university's corporate systems and on technical approaches that reduce implementation risks while preserving data quality and security.

Educational institutions use a variety of ERP systems and local subsystems with heterogeneous data schemas. An effective solution is an integration layer with field mapping and schema versioning, implemented via a REST API and data-normalization services. Incoming PDF files may be digital or scanned; document-type detection, image preprocessing, hybrid OCR, and subsequent processing with regular expressions improve extraction accuracy. For matching disciplines, embeddings and vector-database search with similarity thresholds are applied. A microservice architecture, containerization, and asynchronous processing provide scalability and resilience. Deployment requires integration tests, quality metrics, monitoring, logging, as well as documentation and user training.

[1] The work was carried out within the framework of the State Assignment № FSGF-2024-0006 «Development of new models and methods of decision-making in multi-level management systems».

Solving the two-stage assortment management scheme for small-scale wholesale trade using exact methods[1]

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Abstract. Modern small-scale wholesale trade faces a fundamental challenge: the need for prompt and cost-effective management of product assortments under conditions of high demand volatility. Intuitive and heuristic methods for forming an assortment matrix lead to systemic imbalances – overstocking of illiquid assets, working capital deficits, and inefficient use of warehouse capacity. A promising direction for overcoming these limitations is the application of two-stage optimization schemes, which allow for the separation of strategic planning tasks from tactical adaptation to resource constraints. However, the practical implementation of such models requires a careful selection of tools capable of delivering precise solutions.

The aim of this study is an experimental comparative analysis of applied software products and mathematical solvers designed to implement two-stage assortment management schemes in small-scale wholesale trade. This research focuses exclusively on computational aspects: evaluating the efficiency, convergence speed, and accuracy of solutions obtained using various tools based on a formalized two-stage model.

The empirical basis of the study is formed by the Gurobi Optimizer and IBM ILOG CPLEX Optimization Studio solvers, which serve as industry standards and demonstrate high performance in solving mixed-integer linear programming problems. Verification of the results obtained is carried out by referring to the open-source, non-commercial solver SCIP, which is widely used in academia for research purposes. Additionally, the Gornova optimizer is included in the comparative analysis.

[1] The work was carried out within the framework of the State Assignment № FSGF-2024-0006 «Development of new models and methods of decision-making in multi-level management systems».

Tabu-search with neural network acceleration for the Public–Private Partnership problem

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Abstract. We consider the bilevel 0-1 linear programming problem arising in the planning of public-private partnership (PPP) projects. To find near optimal solution, we design a stochastic tabu-search heuristic. Unfortunately, we have to solve a lot of NP-hard lower-level subproblems for each step of the method. To overcome this obstacle, we accelerate the search by neural network to estimate the promise of neighborhood solutions. The neural network is trained in a hybrid manner: offline on a history of previously solved PPP instances, and online using data collected from earlier iterations. The approach is tested on the semi-synthetic instances for the Transbaikalian polymetallic fields.

Optimization of the PID-regulator model parameters for TEC temperature laser diode controller[1]

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Abstract. Precise temperature stabilization of laser diodes is critical for ensuring single-mode generation in quantum optics experiments, yet existing PID tuning methods often fail to achieve the required accuracy. This study addresses the optimization problem of finding PID controller gains that minimize the Integral Time Absolute Error (ITAE)subject to constraints on overshoot, settling time, and steady-state error. A comparative analysis of nine controller configurations was conducted employing six distinct optimization algorithms: Artificial Rabbits Optimization (ARO), Gradient-Based Optimizer (GBO), Grey Wolf Optimizer (GWO), Particle Swarm Optimization (PSO), Bayesian optimization, and neural network approaches. The optimization landscape was explored using the "Smart Manufacturing Adaptive Control Dataset" as a baseline, revealing that conventional configurations yield a mean error rate far above the experimental requirement. Convergence analysis demonstrates that metaheuristic algorithms successfully navigate the non-convex parameter space, with the ARO algorithm achieving the best ITAE value while satisfying all constraints. The ARO-optimized PID controller attained improved steady-state error, settling time, and overshoot compared to conventional methods. Furthermore, we show that the obtained solution satisfies sufficient conditions for asymptotic stability of the closed-loop system via Lyapunov's direct method. The proposed framework enables high-precision temperature control on an accessible microcontroller platform and establishes a rigorous optimization foundation for extending to diffraction grating positioning and injection current stabilization problems.

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Shortest Path with Precautionary Avoidance Algorithm[1]

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Abstract. This paper addresses the Dynamic Vehicle Routing Problem (DVRP) within uncertain environments characterised by dynamic obstacles. Classical models often assume static information, necessitating immediate replanning when obstacles occur. We propose the Shortest Path with Precautionary Avoidance (SPPA) algorithm, designed for optimal strategic routing under uncertainty. SPPA extends the classical A* evaluation function by incorporating continuous obstacle coeffcients, balancing path effciency with afety considerations beyond binary passability maps. The method decomposes the NP-hard Vehicle Routing Problem into sequential shortest-path subproblems, significantly reducing computational overhead while maintaining robust solution quality. Theoretical analysis confirms a polynomial computational complexity. Experimental results demonstrate that SPPA outperforms established benchmarks, including K-Nearest Neighbours, Ant Colony Optimisation, and standard A* modifications. Specifically, SPPA achieved up to a 59% reduction in computation time compared to KNN and consistently produced shorter routes across varying monitoring point configurations. Furthermore, derived approximation bounds provide theoretical guarantees on solution quality. This validates hybrid optimisation strategies combining exact subproblem solutions with greedy heuristics, making the algorithm particularly suitable for real-time robotic monitoring systems where environmental conditions fluctuate frequently.

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