# ~~A Reinforcement-Learning-Based 3-D Estimation of Distribution Algorithm for Fuzzy Distributed Hybrid Flow-Shop Scheduling Considering On-Time-Delivery~~

~~Deng, Libao Di, Yuanzhu Wang, Ling~~

~~Abstract no encontrado~~

[Paper](https://www.webofscience.com/api/gateway?GWVersion=2&SrcApp=edas&SrcAuth=WosAPI&KeyUT=WOS:001129721600001&DestLinkType=FullRecord&DestApp=WOS_CPL)

# Keep it unbiased: a comparison between estimation of distribution algorithms and deep learning for human interaction-free side-channel analysis

Rioja, Unai Batina, Lejla Armendariz, Igor Flores, Jose Luis

Evaluating side-channel analysis (SCA) security is a complex process, involving applying several techniques whose success depends on human engineering. Therefore, it is crucial to avoid a false sense of confidence provided by non-optimal (failing) attacks. Different alternatives have emerged lately trying to mitigate human dependency, among which deep learning (DL) attacks are the most studied today. DL promise to simplify the procedure by e.g. evading the need for point of interest (POI) selection, among other shortcuts. However, including DL in the equation comes at a price, since working with neural networks is not straightforward in this context. Recently, an alternative has appeared with the potential to mitigate this dependence without adding extra complexity: estimation of distribution algorithm-based SCA. From the perspective of avoiding the need for POI selection, in this paper we provide a comparison of the two relevant methods. Our findings are supported by experimental results on various datasets.

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# The Competing Genes Evolutionary Algorithm: Avoiding Genetic Drift Through Competition, Local Search, and Majority Voting

Ajimakin, Adetunji David Devi, V. Susheela

An estimation-of-distribution algorithm is an evolutionary algorithm that uses a probabilistic model to represent its population. It iteratively draws solutions from its model and, considering their fitnesses, uses these solutions to update the model's parameters. However, there is a risk of reinforcing random noise from sampling back into the model-a problem termed genetic drift. We propose the competing genes evolutionary algorithm that optimizes a fitness function over a binary search space and avoids this problem by updating only one model parameter at a time. The algorithm uses the model not only to sample solutions but also to select a parameter in each iteration that it pins to a value for the rest of the search process. We obtain upper bounds on the number of fitness evaluations the algorithm needs to solve well-known benchmark functions as a function of its population size and observe better or comparable results to other evolutionary algorithms. We attribute these favorable results to the algorithm's efficient use of its samples to explore its dwindling search space. We also introduce two variants of the algorithm. The first version eliminates the need to preset the number of solutions to sample per iteration, and the second seeks to escape local optima. We provide evidence that these variants achieve their goals.

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# ~~Choosing the right algorithm with hints from complexity theory~~

~~Wang, Shouda Zheng, Weijie Doerr, Benjamin~~

~~Choosing a suitable algorithm from the myriads of different search heuristics is difficult when faced with a novel optimization problem. In this work, we argue that the purely academic question of what could be the best possible algorithm in a certain broad class of black-box optimizers can give fruitful indications in which direction to search for good established heuristics. We demonstrate this approach on the recently proposed DLB benchmark. Our finding that the unary unbiased black-box complexity is only O (n2) suggests the Metropolis algorithm as an interesting candidate and we prove that it solves the DLB problem in quadratic time. We also prove that better runtimes cannot be obtained in the class of unary unbiased algorithms. We therefore shift our attention to algorithms that use the information of more parents to generate new solutions and find that the significance-based compact genetic algorithm can solve the DLB problem in time O (n log n).(c) 2023 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons .org /licenses /by-nc -nd /4 .0/).~~

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# Process optimization of microbial fermentation with parameter uncertainties via distributionally robust discrete control

Wang, Juan Chen, Chihua Zhao, Feiyan Wang, Jichao Li, An

There are some uncertain kinetic parameters in microbial fermentation system because of the unclear intracel-lular metabolic mechanisms. Considering the affection of these uncertain parameters on system performance, dynamic process optimization of the fermentation system can be modeled as a distributionally robust discrete control problem under moment uncertainty, which aims to maximize the mean productivity by optimizing the discrete-valued dilution rate function. Based on duality theory, the established min-max discrete optimal control problem is first transformed into a single level minimization problem, which is then discretized into a large-scale parameter optimization problem with semi-infinite constraint via time transformation and control parameterization. A new two-step estimation of distribution algorithm is developed to solve the obtained large-scale optimization problem. Numerical results show the feasibility and effectiveness of the proposed solution approach together with the superiority of the obtained control strategy considering parameter uncertainties.

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# Towards explainable metaheuristics: Feature extraction from trajectory mining

Fyvie, Martin Mccall, John A. W. Christie, Lee A. Brownlee, Alexander E. I. Singh, Manjinder

Explaining the decisions made by population-based metaheuristics can often be considered difficult due to the stochastic nature of the mechanisms employed by these optimisation methods. As industries continue to adopt these methods in areas that increasingly require end-user input and confirmation, the need to explain the internal decisions being made has grown. In this article, we present our approach to the extraction of explanation supporting features using trajectory mining. This is achieved through the application of principal components analysis techniques to identify new methods of tracking population diversity changes post-runtime. The algorithm search trajectories were generated by solving a set of benchmark problems with a genetic algorithm and a univariate estimation of distribution algorithm and retaining all visited candidate solutions which were then projected to a lower dimensional sub-space. We also varied the selection pressure placed on high fitness solutions by altering the selection operators. Our results show that metrics derived from the projected sub-space algorithm search trajectories are capable of capturing key learning steps and how solution variable patterns that explain the fitness function may be captured in the principal component coefficients. A comparative study of variable importance rankings derived from a surrogate model built on the same dataset was also performed. The results show that both approaches are capable of identifying key features regarding variable interactions and their influence on fitness in a complimentary fashion.

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# A Two-Stage Estimation of Distribution Algorithm With Heuristics for Energy-Aware Cloud Workflow Scheduling

Xie, Yi Wang, Xue-Yi Shen, Zi-Jun Sheng, Yu-Han Wu, Gong-Xing

With the enormous increase in energy usage by cloud data centers for handling various workflow applications, the energy-aware cloud workflow scheduling has become a hot issue. However, there is still a need and room for improvement in both the model for estimating workflow energy consumption and the algorithm for energy-aware cloud workflow scheduling. To fill these gaps, a new model for estimating the energy consumption of the cloud workflow execution and a novel Two-Stage Estimation of Distribution Algorithm with heuristics (TSEDA) for energy-aware cloud workflow scheduling are proposed based on the relationships among scheduling scheme, host load and power. In particular, in the proposed TSEDA, a new probability model and its updating mechanism are presented, and a two-stage coevolution strategy with some novel heuristic methods for individual generation, decoding and improvement is designed. Extensive experiments are conducted on workflow applications with various sizes and types, and the results show that the proposed TSEDA outperforms conventional algorithms.

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# Dispatch of highly renewable energy power system considering its utilization via a data-driven Bayesian assisted optimization algorithm

Yu, Chaofan Li, Yuanzheng Liu, Yun Ge, Leijiao Wang, Hao Luo, Yunfeng Pan, Linqiang

In recent years, renewable energy (RE) has been widely deployed, and the power system with high penetration RE is gradually formed. However, the high proportion of RE may threaten transmission security of power systems, which in turn limits its utilization. What is more, the interaction between RE penetration and power system transmission security has not been comprehensively investigated so far. To this end, we develop a bi-objective stochastic dispatch model to investigate the relationship between RE utilization and transmission security. It aims to solve the optimal power system dispatch (OPSD) problem with high penetration RE, in which the RE curtailment and the capacity margin of transmission lines are considered as two objectives of the dispatch problem and formulated in the probabilistic forms. With this, the proposed model is a complicated bi-objective stochastic optimization problem, which is difficult to be solved for traditional optimization algorithms. Therefore, we propose a data-driven Bayesian assisted optimization (DBAO) algorithm, based on Bayesian evolutionary optimization and estimation of distribution algorithm to improve the searching efficiency for the proposed model. Case studies on a modified Midwestern US power system verify the effectiveness of our proposed dispatch model and the optimization algorithm of DBAO.

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# An Interactive Estimation of the Distribution Algorithm Integrated with Surrogate-Assisted Fitness

Qiao, Zhanzhou Guo, Guangsong Zhang, Yong

To accurately model user preference information and ensure the symmetry or similarity between real user preference and the estimated value in product optimization design, an interactive estimation of a distribution algorithm integrated with surrogate-assisted fitness evaluation (SAF-IEDA) is proposed in this paper. Firstly, taking the evaluation information of a few individuals as training data, a similarity evaluation method between decision variables is proposed. Following that, a preference probability model is built to estimate the distribution probability of decision variables. Then, the preference utility function of individuals is defined based on the similarity of decision variables. Finally, the surrogate-assisted fitness evaluation is realized by optimizing the weight of the decision variables' similarities. The above strategies are incorporated into the interactive estimation of the distribution algorithm framework and applied to address the optimal product design problem and the indoor lighting optimization problem. The experimental results demonstrate that the proposed method outperforms the comparative method in terms of search efficiency and fitness prediction accuracy.

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# ~~An Estimation of Distribution Algorithm With Resampling and Local Improvement for an Operation Optimization Problem in Steelmaking Process~~

~~Tang, Lixin Liu, Chang Liu, Jiyin Wang, Xianpeng~~

~~This article studies an operation optimization problem in a steelmaking process. Shortly before the tapping of molten steel from the basic oxygen furnace (BOF), end-point control measures are applied to achieve the required final molten steel quality. While it is difficult to build an exact mathematical model for this process, the control inputs and the corresponding outputs are available by collecting production data. We build a data-driven model for the process. To optimize the control parameters, an improved estimation of distribution algorithm (EDA) is developed using a probabilistic model comprising different distributions. A resampling mechanism is incorporated into the EDA to guide the new population to a broader and more promising area when the search becomes ineffective. To further enhance the solution quality, we add a local improvement to update the current best individual through simplified gravitational search and information learning. Experiments are conducted using real data from a BOF steelmaking process. The results show that the algorithm can help to achieve the specified molten steel quality. To evaluate the proposed algorithm as a general optimization algorithm, we test it on some complex benchmark functions. The results illustrate that it outperforms other state-of-the-art algorithms across a wide range of problems.~~

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# Marginal Distribution Algorithm for Feature Model Test Configuration Generation

Sahid, Mohd Zanes Saringat, Mohd Zainuri Hamzah, Mohd Hamdi Irwan Zainal, Nurezayana

Generating test configuration for Software Product Line (SPL) is difficult, due to the exponential effect of feature combination. Pairwise testing can generate test input for a single software product that deviates from exhaustive testing, nevertheless proven to be effective. In the context of SPL testing, to generate minimal test configuration that maximizes pairwise coverage is not trivial, especially when dealing with a huge number of features and when constraints must be satisfied, which is the case in most SPL systems. In this paper, we propose an estimation of distribution algorithm, based on pairwise testing, to alleviate this problem. Comparisons are made against a greedy based and a constraint handling based approach. The experiments demonstrate the feasibility of the proposed algorithm, such that it achieves better test configurations dissimilarity and at the same time maintain the test configuration size and pairwise coverage. This is supported by analysis using descriptive statistics.

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# A knowledge-driven co-evolutionary algorithm assisted by cross-regional interactive learning

Zhu, Ningning Zhao, Fuqing Cao, Jie Jonrinaldi

Differential evolution (DE) and Estimation of distribution algorithm (EDA) exhibit complementary superiority in solving complex continuous optimization and engineering problems. The design of appropriate strategies coordinated with the two algorithms to balance exploration and exploitation is conducive to obtaining high-precision solutions. A knowledge-driven co-evolutionary algorithm assisted by a cross-regional interactive learning mechanism (KCACIL) is proposed to achieve a comprehensive collaboration between the algorithms, diverse strategies, and cross-regional individuals. Various elite-guided mutation strategies and a self-feedback strategy based on successful experience in light of implicit knowledge are devoted to fulfilling self-learning and crossregional interactive learning to accomplish individual collaboration and knowledge transfer in the three regions. Reinforcement learning based on &amp; epsilon; - greedy and simulated annealing is employed as feedback on the crossregional individual information to promote the collaboration between opposition-based learning, interaction learning mechanism, and the revised strategy of inferior solutions with small Q values and high distance density. The dynamic self-adaptive adjustment strategies of multiple parameters are adopted to balance diversity and convergence. KCACIL is verified on the CEC 2014, 2017, 2020 benchmark test suites, and engineering applications. Experimental results indicate KCACIL is superior to the state-of-the-art comparison algorithms.

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# Simultaneous Scheduling of Processing Machines and Automated Guided Vehicles via a Multi-View Modeling-Based Hybrid Algorithm

Xin, Bin Lu, Sai Wang, Qing Deng, Fang Shi, Xiang Cheng, Jun Kang, Yuhang

The flexible job-shop co-scheduling problem (FJCSP) for processing machines and automated guided vehicles (AGVs) in a flexible manufacturing system (FMS) has attracted more attention with the aim of improving production efficiency. In FMS, AGVs in charge of transporting jobs realize the flexible linkage of operations between different processing machines. The added interdependence between transporting and processing tasks brings more difficulties than the traditional flexible job-shop scheduling problem (FJSP). In this paper, the mathematical model of FJCSP is formulated to minimize the makespan. Considering the feature similarity of FJCSP with FJSP and AGV-routing problem in different cases, a multi-view modeling-based hybrid algorithm consisting of an estimation of distribution algorithm (EDA) and an ant colony optimization (ACO) is proposed. In EDA, a probability model abstracts the information in superior solutions about the operation sequencing and the rule selection for scheduling machines and AGVs. In ACO, a jobpath pheromone model and an AGV-path pheromone model are designed to jointly select the job-machine-AGV combination with shorter processing time and transportation time. In the proposed hybrid algorithm, EDA and ACO generate solutions indepen- dently and achieve cooperation by sharing elites. An adaptive parameter is designed to regulate the use of the two methods to adapt to the varying demands of multi-view modeling in different cases and search stages. Furthermore, a local search with a three-layer operator based on the critical path method is proposed to balance exploration and exploitation in solution space. Finally, computational experiments involving a case study verified the advantage of the multi-view modeling-based hybrid algorithm in comparison with the state-of-the-art approaches.

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# A knowledge-based constructive estimation of distribution algorithm for bi-objective portfolio optimization with cardinality constraints

Zhang, Zhi-Xuan Chen, Wei-Neng Hu, Xiao-Min

Portfolio optimization is an essential and practical model for financial decision making. With the consideration of some real-world constraints, especially the cardinality constraints, the problem becomes much more challenging as it converts to a mixed-integer quadratic multi-objective optimization problem. To solve this problem, we propose a knowledge-based constructive estimation of distribution algorithm (KC-EDA) with the following three features. First, a hybrid design of Ant colony optimization (ACO) and Estimation distribution algorithm (EDA) is used to solve this mixed-variable optimization problem based on knowledge information. Second, a knowledge accumulation mechanism is designed to discover the internal relationship among the assets. The mechanism can not only guide the selection of assets effectively but also enable the use of historical information during evolution to direct the allocation of investment proportion. Third, a constructive approach is applied to construct portfolios under the constraints. This hybrid and constructive approach is incorporated into the multiobjective evolutionary framework and the experiment has been performed on the SZ50, SZ180, and SZ380 datasets (from January 2014 to December 2018). The experimental results demonstrate the effectiveness of KC-EDA in solving the portfolio optimization problem with cardinality constraints.&amp; COPY; 2023 Published by Elsevier B.V.

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# The Directed Multi-Objective Estimation Distribution Algorithm (D-MOEDA)

Botello-Aceves, Salvador Hernandez-Aguirre, Arturo Valdez, S. Ivvan

Improvement Direction Mapping (IDM) methods have been applied as a local search strategy to hybridize global search algorithms. A natural question is whether this concept could be applied within a global search scheme, so that the stochastic search operators are directed toward promising regions, promoting a more efficient search. This paper introduces a novel Multi-Objective Evolutionary Algorithm (MOEA) that incorporates the IDM into the reproduction operator of an Estimation of Distribution Algorithm (EDA). In this proposal, the search directions of the IDM based on aggregation functions are used to directly steer the search process of a multi-objective evolutionary algorithm based on decomposition, by orienting a local probability distribution towards a search direction, the proposal intends to steer solutions toward the Pareto front (PF) of the Multi-Objective Optimization Problem (MOP), exploiting the search features of the aggregation functions. The proposal is tested using a set of well-known benchmark MOPs and compared to state of the art MOEAs. Results showed statistical evidence about the importance of the orientation of the search probability distribution to improve the convergence to the Pareto front.&amp; COPY; 2023 International Association for Mathematics and Computers in Simulation (IMACS). Published by Elsevier B.V. All rights reserved.

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# An Estimation of Distribution Algorithm for Permutation Flow-Shop Scheduling Problem

Lemtenneche, Sami Bensayah, Abdallah Cheriet, Abdelhakim

Estimation of distribution algorithms (EDAs) is a subset of evolutionary algorithms widely used in various optimization problems, known for their favorable results. Each generation of EDAs builds a probabilistic model to represent the most promising individuals, and the next generation is created by sampling from this model. The primary challenge in designing such algorithms lies in effectively constructing the probabilistic model. The mutual exclusivity constraint imposes an additional challenge for EDAs to approach permutation-based problems. In this study, we propose a new EDA called Position-Guided Sampling Estimation of Distribution Algorithm (PGS-EDA) specifically designed for permutation-based problems. Unlike conventional approaches, our algorithm focuses on the positions rather than the elements during the sampling phase. We evaluate the performance of our algorithm on the Permutation Flow-shop Scheduling Problem (PFSP). The experiments conducted on various sizes of Taillard instances provide evidence of the effectiveness of our algorithm in addressing the PFSP, particularly for small and medium-sized problems. The comparison results with other EDAs designed to handle permutation problems demonstrate that our PSG-EDA algorithm consistently achieves the lowest Average Relative Percentage Deviation (ARPD) values in 19 out of the 30 instances of sizes 20 and 50 used in the study. These findings validate the superior performance of our algorithm in terms of minimizing the makespan criterion of the PFSP.

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# ~~An improved estimation of distribution algorithm for rescue task emergency scheduling considering stochastic deterioration of the injured~~

~~Xu, Ying Li, Xiaobo Li, Qian Zhang, Weipeng~~

~~Efficient allocating and scheduling emergency rescue tasks are a primary issue for emergency management. This paper considers emergency scheduling of rescue tasks under stochastic deterioration of the injured. First, a mathematical model is established to minimize the average mathematical expectation of all tasks' completion time and casualty loss. Second, an improved multi-objective estimation of distribution algorithm (IMEDA) is proposed to solve this problem. In the IMDEA, an effective initialization strategy is designed for obtaining a superior population. Then, three statistical models are constructed, which include two tasks existing in the same rescue team, the probability of first task being processed by a rescue team, and the adjacency between two tasks. Afterward, an improved sampling method based on referenced sequence is employed to efficiently generate offspring population. Three multi-objective local search methods are presented to improve the exploitation in promising areas around elite individuals. Furthermore, the parameter calibration and effectiveness of components of IMEDA are tested through experiments. Finally, the comprehensive comparison with state-of-the-art multi-objective algorithms demonstrates that IMEDA is a high-performing approach for the considered problem.~~

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# Parameter estimation for empirical and semi-empirical models in a direct ethanol fuel cell

Blanco-Cocom, Luis Botello-Rionda, Salvador Ordonez, L. C. Valdez, S. Ivvan

Experimental data from a Direct Ethanol Fuel Cell (DEFC) provides a general perspective about its performance; nevertheless, it does not provide information about the cell's physical characteristics nor information to improve its performance. On the other hand, numerical simulation can be used to test the cell's design and boost its performance but requires a set of physical parameters. In this proposal, we introduce a novel modification to an empirical model for a Direct Methanol Fuel Cell to make it suitable for DEFC simulations at different temperatures by a new semi-empirical mathematical model. In addition, we introduce temperature-depending parametric forms of several terms to reduce the number of possible parameters to estimate from the DEFC. Then, we combined the models with an estimation of distribution algorithm to find the numerical simulation that best reproduces the experimental polarization curve. The method is validated by estimating the parameters to reproduce the experimental data at different temperatures reported in the literature, and with data obtained in an in-house open-cathode DEFC, recorded at a scan rate of 10 mVs-1, using as fuel CH3CH2OH 1 M at 25 degrees C and 60 degrees C. From the estimation results at temperature set T ⃗1 = (T1a, T1c) degrees C, the same parameters are used for a simulation at T2 ⃗ = (T2a, T2c) degrees C, demonstrating that it reproduces the two experimental polarization curves. Hence, the models and methods presented here can be used to reduce physical experimentation and to test different designs and operation settings.&amp; COPY; 2023 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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# Initial core loading pattern optimization studies using estimation of distribution algorithm for VVER type cores

Thakur, Amit Srivastava, Argala Kumar, Vaibhav Bhatt, Kislay Duggal, Vibhuti Rajesh, K. Kannan, Umasankari

Innovative fuel management schemes based on evolutionary algorithms (EAs) now form an integral part of design and operation for nuclear reactors. In the present study, Estimation of Distribution Algorithm (EDA) has been developed for light water reactors (LWRs) and as a case study EDA has been applied to optimize the core loading pattern of VVER X2 benchmark's initial core. EDA belongs to class of EAs where the optimization solution evolves through progress of generations and in each generation sampling of best candidates of previous generation is done. The main objectives of this study is firstly to develop and test EDA to optimize core loading pattern (LP) for VVER type cores and secondly to generate new optimized LPs having same safety features but with improved fuel utilization with respect to reference benchmark case. The most suitable values for internal parameters for EDA like population size (N), percentage best candidates (M) and weighting factor '&amp; alpha;' were evaluated for reaching a reasonable optimized solution in computationally efficient way. During this study, a number of optimized initial core loading patterns were generated, where the target parameters and safety limits are met. A comprehensive analysis for selected LPs has been carried out for full cycle and a comparison has been done for the reported safety and operational characteristics. It is observed that a few of the optimized LPs have better fuel economy than the benchmark LP.

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# Research on gas emission quantity prediction model based on EDA-IGA

Ji, Peng Shi, Shiliang Shi, Xingyu

In order to accurately predict the possible gas emission quantity in coal mines, it is proposed to use the multi-thread calculation of the Immune Genetic Algorithm (IGA) and injection of vaccines to improve the accuracy of prediction and combine the Estimation of Distribution Algorithm (EDA) to the distribution probability of excellent populations. Calculating, and selecting excellent populations for iteration, optimize the population generation process of the Immune Genetic Algorithm, so that the population quality is continuously optimized and improved, and the optimal solution is obtained, thereby establishing a gas emission quantity prediction model based on the Immune Genetic Algorithm and Estimation of Distribution Algorithm. Using the 9136 mining face with gas emission hazards in a coal mine from Shandong Province in China as the prediction object, the absolute gas emission quantity is used to scale the gas emission quantity, and it is found that the model can accurately predict the gas emission quantity, which is consistent with the on-site emission unanimous. In the prediction comparison with IGA, it is found that the accuracy of the prediction results has increased by 9.51%, and the number of iterations to achieve the required goal has been reduced by 67%, indicating that the EDA has a better role in optimizing the population update process such as genetic selection of the IGA. Comparing the prediction results of other models, it is found that the prediction accuracy of the EDA-IGA is 94.93%, which is the highest prediction accuracy, indicating that this prediction model can be used as a new method for the prediction of coal mine gas emission. Accurately predicting the gas emission quantity can provide guidance for safe mining in coal mines. The gas emission quantity can also be used as a safety indicator to reduce the possibility of coal mine accidents, ensure the personal safety of coal miners and reduce economic losses in coal mines.

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# FEDA-NRP: A fixed-structure multivariate estimation of distribution algorithm to solve the multi-objective Next Release Problem with requirements interactions

Perez-Piqueras, Victor Bermejo, Pablo Gamez, Jose A.

In the development of a software product, the Next Release Problem is the selection of the most appropriate subset of requirements (tasks) to include in the next release of the product, such that the selected subset maximises the overall satisfaction of the stakeholders and minimises the total cost. Furthermore, in most cases, requirements or tasks cannot be developed independently, as there are dependencies between them, which must be respected in the selection for the next release. In this paper, we approach the Next Release Problem as a constrained bi-objective optimisation problem. The main contribution is the design of an Estimation of Distribution Algorithm that exploits domain knowledge, i.e. the dependencies between the requirements, to define the structure of a Bayesian network that models the relationships between the binary variables (requirements) to be optimised. The use of a Bayesian network with a fixed structure reduces the complexity of the search process, since it is unnecessary to learn the structure at each iteration of the algorithm. Moreover, it ensures that the sampled individuals are always valid with respect to the required dependencies. The second main contribution is the generation of a corpus of synthetic datasets with cost estimations derived from agile and classic management methodologies. Standard multi-objective metrics are computed in order to assess our proposal and compare it with other evolutionary multi-criterion optimisation algorithms, determining that it is the optimal choice when dealing with complex datasets.

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# Metaheuristic-based time series clustering for anomaly detection in manufacturing industry

Suh, Woong Hyun Oh, Sanghoun Ahn, Chang Wook

Nowadays time series clustering is of great importance in manufacturing industries. Meanwhile, it is considerably challenging to achieve explainable solution as well as significant performance due to computation complexity and variable diversity. To efficaciously handle the difficulty, this paper presents a novel metaheuristic-based time series clustering method which can improve the effectiveness and logicality of existing clustering approaches. The proposed method collects candidate cluster references from hierarchical and partitional clustering through shape-based distance measure as well as dynamic time warping (DTW) on manufacturing time series data. By applying metaheuristics highlighting estimation of distribution algorithms (EDA), such as extended compact genetic algorithm (ECGA), on the collected candidate clusters, advanced cluster centroid combinations with minimal distances can be achieved. ECGA employs the least complicated and the most closely related probabilistic model structure regarding population space during generation cycle. This feature strengthens the comprehension of clustering results in how such optimal solutions were achieved. The proposed method was tested on real-world time series data, open to the public, from manufacturing industry, and showed noticeable performances compared to well-established methods. Accordingly, this paper demonstrates that obtaining both comprehensible result as well as prominent performance is feasible by employing metaheuristic techniques to time series data clustering methods.

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# ~~A hybrid estimation of distribution algorithm for the offline 2D variable-sized bin packing problem~~

~~Borgulya, Istvan~~

~~In this paper we present an evolutionary heuristic for the offline two-dimensional variable-sized bin packing problem. In this problem we have to pack a set of rectangles into two-dimensional variable-sized rectangular bins. The bins are divided into types, and the bins in different types have different sizes and possibly different weights (costs). There are (sufficiently) many bins from each type, and any rectangle fits into at least one bin-type. The goal is to pack the rectangles into the bins without overlap, parallel to the sides, so that the total area of the used bins (or total cost) is minimized. Our algorithm is a hybrid heuristic. It uses two different techniques to generate the descendants: either estimation of distribution algorithm and sampling the resulting probability model, or applying the usual operators of evolutionary algorithms (selection, mutation). To pack the rectangles into the bins the algorithm uses the strategy of randomly choosing one of two placement heuristics, that pack always only one group (one to three) of rectangles. It improves the quality of the solutions with three local search procedures. The algorithm has been tested on benchmark instances from the literature and has been compared with other heuristics and metaheuristics. Our algorithm outperformed the previously published results.~~

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# Using an Estimation of Distribution Algorithm to Achieve Multitasking Semantic Web Service Composition

Wang, Chen Ma, Hui Chen, Gang Hartmann, Sven

Web service composition composes existing Web services to accommodate users' requests for required functionalities with the best possible quality of services (QoS). Due to the computational complexity of this problem, evolutionary computation (EC) techniques have been employed to efficiently find composite services with near-optimal functional quality (i.e., quality of semantic matchmaking, QoSM for short) or nonfunctional quality (i.e., QoS) for each composition request individually. With a rapid increase in composition requests from a growing number of users, solving one composition request at a time can hardly meet the efficiency target anymore. Driven by the idea that the solutions obtained from solving one request can be highly useful for tackling other related requests, multitasking service composition approaches have been proposed to efficiently deal with multiple composition requests concurrently. However, existing attempts have not been effective in learning and sharing knowledge among solutions for multiple requests. In this article, we model the problem of collectively handling multiple service composition requests as a new multitasking service composition problem and propose a new permutation-based multifactorial evolutionary algorithm based on an estimation of distribution algorithm (EDA), named PMFEA-EDA, to effectively and efficiently solve this problem. In particular, we introduce a novel method for effective knowledge sharing across different service composition requests. For that, we develop a new sampling mechanism to increase the chance of identifying high-quality service compositions in both the single-tasking and multitasking contexts. Our experiment shows that our proposed approach, PMFEA-EDA, takes much less time than existing approaches that process each service request separately, and also outperforms them in terms of both QoSM and QoS.

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# A Deadlock-Free Hybrid Estimation of Distribution Algorithm for Cooperative Multi-UAV Task Assignment With Temporally Coupled Constraints

Zhang, Ruipeng Feng, Yanxiang Yang, Yikang Li, Xiaoling

This article addresses the cooperative multiunmanned aerial vehicles task assignment problem (CMTAP) with temporally coupled constraints and aims to find a feasible assignment to minimize the equivalent distances of all tasks. We first present a mixed-integer linear programming model of CMTAP. To solve the undesirable deadlocks of CMTAP, a Petri net amender is constructed based on a candidate solution, and a deadlock-free solution is equivalent to a feasible transition sequence that can be fired sequentially in the corresponding amender. With this amender, we present a Petri net-based deadlock amending method (PDAM) with polynomial time complexity to convert a deadlocked solution into a deadlock-free solution. Also, a deadlock-free hybrid estimation of distribution algorithm (DHEDA) is developed for CMTAP by embedding PDAM into the original EDA. To further improve the solution quality, we establish a local exploitation method, and an adaptive operational probability is used to balance the computational burden and local exploitation ability. Then, a match-up-based reassignment method is proposed to cope with time-sensitive targets. Finally, extensive computational experiments demonstrate that PDAM is more effective at solving deadlocks than graph-based methods, particularly for large-scale CMTAP, and DHEDA outperforms existing algorithms when solving CMTAP.

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# The maximal covering location problem with accessibility indicators and mobile units

Vicencio-Medina, Salvador J. Rios-Solis, Yasmin A. Ibarra-Rojas, Omar Jorge Cid-Garcia, Nestor M. Rios-Solis, Leonardo

We study the Maximal Covering Location Problem with Accessibility Indicators and Mobile Units that maximizes the facilities coverage, the accessibility of the zones to the open facilities, and the spatial disaggregation. The main characteristic of our problem is that mobile units can be deployed from open facilities to extend the coverage, accessibility, and opportunities for the inhabitants of the different demand zones. We formulate the Maximal Covering Location Problem with Accessibility Indicators and Mobile Units as a mixed-integer linear programming model. To solve larger instances, we propose a matheuristic (combination of exact and heuristic methods) composed of an Estimation of Distribution Algorithm and a parameterized Maximal Covering Location Problem with Accessibility Indicators and Mobile Units integer model. To test our methodology, we consider the Maximal Covering Location Problem with Accessibility Indicators and Mobile Units model to cover the low-income zones with Severe Acute Respiratory Syndrome Coronavirus 2 patients. Using official databases, we made a set of instances where we considered the poverty index, number of population, locations of hospitals, and Severe Acute Respiratory Syndrome Coronavirus 2 patients. The experimental results show the efficiency of our methodologies. Compared to the case without mobile units, we drastically improve the coverage and accessibility for the inhabitants of the demand zones.

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# An Estimation of Distribution Algorithm-Based Hyper-Heuristic for the Distributed Assembly Mixed No-Idle Permutation Flowshop Scheduling Problem

Zhao, Fuqing Zhu, Bo Wang, Ling

The distributed assembly mixed no-idle permutation flowshop scheduling problem (DAMNIPFSP), a common occurrence in modern industries like integrated circuit production, ceramic frit production, fiberglass processing, and steel-making, is a new model that considers mixed machines with no-idle restrictions as well as conventional machines. This article introduces an estimation of distribution algorithm-based hyper-heuristic (EDA-HH) to solve the DAMNIPFSP. Ten simple heuristic rules as low-level operations are utilized to search the solution space. The estimation of distribution algorithm is integrated into the framework of hyper-heuristic as the high-level strategy to control the low-level heuristics sequence in the solution space. The destruction and construction procedures are conducted on products and jobs in order to enhance the exploitation competence of EDA-HH. The computational simulation is carried out and the experimental results show that the proposed EDA-HH is significantly superior to the competitors in the statistical sense. The results of the 810 large-scale problem instances show the effectiveness of the EDA-HH in solving the DAMNIPFSP. Moreover, the CPLEX solver is utilized to verify the correctness of the model with some small instances.

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# A distribution evolutionary algorithm for the graph coloring problem

Xu, Yongjian Cheng, Huabin Xu, Ning Chen, Yu Xie, Chengwang

Graph coloring is a challenging combinatorial optimization problem with a wide range of applications. In this paper, a distribution evolutionary algorithm based on a population of probability model (DEA-PPM) is developed to address it efficiently. Unlike existing estimation of distribution algorithms where a probability model is updated by generated solutions, DEA-PPM employs a distribution population based on a novel probability model, and an orthogonal exploration strategy is introduced to search the distribution space with the assistance of an refinement strategy. By sampling the distribution population, efficient search in the solution space is realized based on a tabu search process. Meanwhile, DEA-PPM introduces an iterative vertex removal strategy to improve the efficiency of k-coloring, and an inherited initialization strategy is implemented to address the chromatic number problem well. The cooperative evolution of the distribution population and the solution population leads to a good balance between exploration and exploitation. Numerical results demonstrate that the DEA-PPM of small population size is competitive to the state-of-the-art metaheuristics.

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# A co-evolutionary migrating birds optimization algorithm based on online learning policy gradient

Zhao, Fuqing Jiang, Tao Xu, Tianpeng Zhu, Ningning Jonrinaldi

A co-evolutionary migrating birds optimization algorithm based on online learning policy gradient (CMBO-PG) is proposed to address complex continuous real-parameter optimization problems. In CMBO-PG, a Gaussian estimation of distribution algorithm (GEDA), which enhances the exploitation tendency, is utilized to generate the solutions of the leading flock. The neighborhood solutions of the following flock are produced by a multi-strategy learning mechanism to promote exploration capability. The co-evolution of the leading flock and following flock is realized by the information-sharing mechanism and the operation of destruction and construction to keep the balance of exploration and exploitation. The nonlinear selection of mutation strategies is laborious due to the differences in the ability to address optimization problems. In the mechanism of multi-strategy learning, a long short-term memory (LSTM) is adopted as a selector of mutation strategies to predict the selection probability of three mutation strategies. The evolutionary procedure of the following flock is modeled as a Markov decision process (MDP). The policy gradient (PG) is employed as a model optimizer to control the parameters of LSTM based on the historical feedback information. The performance of CMBO-PG is testified on the CEC 2017 benchmark test suite. The experimental results show that CMBO-PG is superior to the 12 comparison algorithms, including state-of-art algorithms.

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# ~~Knowledge-based multi-objective estimation of distribution algorithm for solving reliability constrained cloud workflow scheduling~~

~~Li, Ming Pi, Dechang Qin, Shuo~~

~~With the rapid development of cloud computing, numerous large-scale workflow are executed in the cloud environment. Therefore, the workflow scheduling in cloud environment has become an emerging topic. This paper focuses on a reliability constrained multi-objective workflow scheduling problem (RCMOWSP) with the objectives of minimum execution cost and time. To solve the RCMOWSP, this paper proposes a knowledge-based multi-objective estimation of distribution algorithm (KMOEDA) with several problem-specific operators. First, an idle time-based decoding scheme is applied to sort the permutation of tasks greedily. In the global search strategy, a probability model is constructed to improve the diversity of population. Based on the problem-specific knowledge, a reliability-aware local search strategy is designed to performs local search around the solutions that violate reliability constraint. An elite enhancement strategy with a task perturbation operator and a resource perturbation operator is introduced to further improve the elite non-dominated solutions in the external archive. A comprehensive experiment is conducted to verify the performance of KMOEDA. The comparative results show that the KMOEDA significantly outperforms several relative multi-objective workflow scheduling approaches in solving the RCMOWSP.~~

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# Manufacturing rescheduling after crisis or disaster-caused supply chain disruption

Bo, Hongguang Chen, Xiao Alison Luo, Qian Wang, Wenpeng

In this paper, we study the problems a repair shop has with rescheduling after major supply disruptions. The repair shop provides repair and maintenance services to its customers. After a major disruption to production, the repair shop faces delays in production and order delivery due to shortages in materials and/or labor, which requires rescheduling of all the unfinished parts. We observe that the finished parts incur high holding costs until the entire order is completed, while any unfinished parts (in the form of raw material or work-in-progress) incur low holding costs until production starts. Moreover, the repair shop incurs a setup cost when switching between different types of parts. Considering these new features, we formulate the rescheduling problem for the repair shop under a coordinated supply chain as an integer program to minimize the total tardiness, setup cost, and holding cost. To solve the model, we propose an innovative two-stage genetic algorithm, which utilizes the estimation of distribution algorithm (EDA) to improve the search process of the optimal solution. We test the performance of this algorithm on a dataset generated from the order data of a heavy machinery maintenance provider. The numerical results show that our model generates solutions that outperform the initial schedule, which was obtained by minimizing holding and setup costs without disruption. In addition, using other closely-related genetic algorithms as benchmarks, we show that our algorithm outperforms the benchmarks without sacrificing the computational time. We also discuss an extension of the main model by considering the recovery of productivity in terms of processing time.

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# An inverse model-guided two-stage evolutionary algorithm for multi-objective optimization

Shen, Jiangtao Dong, Huachao Wang, Peng Li, Jinglu Wang, Wenxin

The estimation of distribution algorithm (EDA) is a kind of distinctive evolutionary algorithm that generates candidate solutions by directly sampling on distribution models. In this paper, we propose a distribution model -guided two-stage evolutionary algorithm for better solving multi-objective optimization problems (MOPs). To enhance modeling efficiency, the clustering method is employed to divide the population into multiple sub -populations. Then multivariate inverse models mapping from the objective space to the decision space are constructed by using a single decision variable and two objectives from each subpopulation. Then offspring are generated by randomly sampling the global and local objective space using the constructed inverse models. Moreover, a two-stage framework is proposed for better quality, i.e., convergence and diversity, of the solution set. In the first stage, exploration is mainly considered, during which the population converge rapidly. And exploitation is emphasized in the second stage, where the solution set is tuned by a replacement strategy. Experimental studies with several peer competitors on a set of widely-used benchmark MOPs as well as an en-gineering design MOP verify the competitiveness of the proposed method.

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# A novel ensemble estimation of distribution algorithm with distribution modification strategies

Wang, Xiaofei Li, Yintong Liang, Yajun Wu, Bi Xuan, Yongbo

The canonical estimation of distribution algorithm (EDA) easily falls into a local optimum with an ill-shaped population distribution, which leads to weak convergence performance and less stability when solving global optimization problems. To overcome this defect, we explore a novel EDA variant with an ensemble of three distribution modification strategies, i.e., archive-based population updating (APU), multileader-based search diversification (MSD), and the triggered distribution shrinkage (TDS) strategy, named E-3-EDA. The APU strategy utilizes historical population information to rebuild the search scope and avoid ill-shaped distributions. Moreover, it continuously updates the archive to avoid overfitting the distribution model. The MSD makes full use of the location differences among populations to evolve the sampling toward promising regions. TDS is triggered when the search stagnates, shrinking the distribution scope to achieve local exploitation. Additionally, the E-3-EDA performance is evaluated using the CEC 2014 and CEC 2018 test suites on 10-dimensional, 30-dimensional, 50-dimensional and 100-dimensional problems. Moreover, several prominent EDA variants and other top methods from CEC competitions are comprehensively compared with the proposed method. The competitive performance of E-3-EDA in solving complex problems is supported by the nonparametric test results.

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# Performance evaluation and optimization model for closed-loop production lines considering preventive maintenance and rework process

Zhou, Binghai Zha, Wenfei

Closed-loop production lines with a constant number of carriers are widely encountered in today's production systems. In this paper, a production performance evaluation and optimization model is proposed for a closed-loop production line taking into account the degradation-level-dependent quality and rework process. Based on a two-machine-one-buffer decomposition method and the system state transition, a production performance evaluation method is presented. Due to the emphasis on quality management, preventive maintenance (PM) is used to ensure the reliability of the machines in the production line, increasing the effective output at minimum cost. A hybrid particle swarm optimization and estimation of distribution algorithm (PSO-EDA) is proposed to efficiently develop the optimal PM strategy. Finally, numerical experiments are performed to verify the effectiveness of the model. With the objective of maximizing the system profit, the optimization of the machines and pallets number is also explored.

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# ~~FRAT: a fuzzy rule based adaptive technique for intelligent placement of UAV-mounted base station~~

~~Mandloi, Dilip Arya, Rajeev~~

~~Unmanned Aerial Vehicle (UAV)-mounted base stations (UmBSs) are a potential approach for quick wireless service recovery in a scenario where the terrestrial network has collapsed or has not been installed. However, identifying the locations, where the minimum number of UmBSs can be deployed to serve the maximum number of Mobile Users (MUs) is one of the fundamental problems of base station deployment. In particular, we aim to reduce the number of UmBSs required and increase the number of MUs served by optimizing the deployment locations of UmBS. To this end, a three-step UmBS deployment approach is proposed. First, utilize K-means, a machine learning-based clustering technique, for the cluster initialization of the UmBSs deployment locations. Next, to ensure the required Quality of Service at MU, the service radius of each UmBS is estimated based on the minimum signal-to-interference plus noise ratio at each MU. Subsequently, a fuzzy rule-based adaptive genetic algorithm termed FRAT is proposed to reduce the number of UmBSs required and to increase the number of MU served. Finally, the effectiveness of the proposed approach is demonstrated using simulation results. Furthermore, the conventional Genetic Algorithm and Estimation of Distribution Algorithm are considered baseline techniques to present the comparative analysis.~~

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# A regularity model-based multi-objective estimation of distribution memetic algorithm with auto-controllable population diversity

Jiang, Qiaoyong Cui, Jianan Wang, Lei Lin, Yanyan Wu, Yali Hei, Xinhong

The regularity model-based multi-objective estimation of distribution algorithm (RM-MEDA) employs the local principal component analysis to split the population into several clusters, and each cluster is used to construct an affine subspace by combing the cluster center, principal components and additional Gaussian noise. However, such affine subspace greatly limits the sampling range of trail solutions, which will lead to the rapid loss of population diversity. To address this issue, an improved RM-MEDA with auto-controllable population diversity (RM-MEDA-AcPD) is suggested in this paper. In RM-MEDA-AcPD, the simplex crossover method is employed to extend the representation range of the affine subspace, the main purpose of which is to push solutions forward along the orthogonal direction of the affine subspace. In addition, a random noise model related to the evolution process is designed to replace the original Gaussian noise model, which reduces the risk of rapid loss of population diversity. In experimental studies, we have compared eight regularity property-based multi-objective evolutionary algorithms with the RM-MEDA-AcPD on benchmark problems with disconnected Pareto fronts. The experimental results demonstrate that the performance of RM-MEDA-AcPD significantly outperforms the other nine comparison algorithms in solving these test instances.

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# A scheduling algorithm for heterogeneous computing systems by edge cover queue

Chen, Yu-meng Liu, Song -lin Chen, Yan-jun Ling, Xiang

In heterogeneous computing systems, excellent task scheduling algorithms can shorten the task completion time and improve system parallelism. With the large-scale deployment of edge computing, the task scheduling algorithm in heterogeneous edge computing servers has become a critical factor in improving the overall system performance. This paper proposes a new task scheduling algorithm called the edge cover scheduling algorithm (ECSA), which schedules tasks based on the edge cover queue of the directed acyclic graph (DAG) for heterogeneous computing systems. Based on the estimation of distribution algorithm (EDA) and the graph random walk algorithm, the ECSA generates an edge cover queue from DAG. Then, the ECSA uses the heuristics greedy method with low time and computational complexity to allocate the edge cover queue to processors. Theoretical analysis and simulation results on random DAGs and real-world DAGs show that the ECSA can achieve better scheduling results in terms of makespan, the schedule length ratio (SLR), efficiency, and frequency of best results with low time and computational complexity.(c) 2023 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

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# An estimation of distribution algorithm based on interactions between requirements to solve the bi-objective Next Release Problem

del Sagrado, Jose Sierra Ibanez, Jose Antonio del Aguila, Isabel M.

Selecting the appropriate requirements to develop in the next release of an open market software product under evolution, is a compulsory step of each software development project. This selection should be done by maximizing stakeholders' satisfaction and minimizing development costs, while keeping constraints. In this work we investigate what is the requirements interactions impact when searching for solutions of the bi-objective Next Release Problem. In one hand, these interactions are explicitly included in two algorithms: a branch and bound algorithm and an estimation of distribution algorithm (EDA). And on the other, we study the performance of these not previously used solving approaches by applying them in several instances of small, medium and large size data sets. We find that interactions inclusion do enhance the search and when time restrictions exists, as in the case of the bi-objective Next Release Problem, EDAs have proven to be stable and reliable locating a large number of solutions on the reference Pareto front.(c) 2023 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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# Aligning heterogeneous optimization problems with optimal correspondence assisted affine transformation for evolutionary multi-tasking

Chen, An Ren, Zhigang Wang, Muyi Su, Shenyu Yun, Jiaqi Wang, Yichuang

Evolutionary multi-tasking optimization (EMTO) aims to boost the overall efficiency of optimizing multiple tasks by triggering knowledge transfer among them. Unfortunately, it may suffer from negative transfer on heterogeneous composite tasks that have low similarity. Some studies try to learn an intertask alignment transformation based on the paired samples from the involved tasks, but risk a failed alignment with improper pairwise methods. To solve this issue, this study proposes an optimal correspondence assisted affine transformation (OCAT) algorithm. OCAT explicitly constructs a mathematical model for the intertask alignment problem and theoretically deduces its optimal solution in an iterative method. As a result, the sample correspondences that enable the learned transformation to achieve the maximum intertask similarity can be located. Besides, a novel approach to deriving the affine transformation formula is also developed for OCAT. The resulting affine alignment transformation will not impair the knowledge contained in the tasks during the alignment process. By integrating OCAT with the estimation of distribution algorithm, this study finally develops a many-tasking optimization algorithm named MaT-EDA, where the solutions from other tasks are explicitly transferred as the samples for estimating the current distribution model. Extensive simulation studies have indicated that OCAT can significantly enhance the performance of EMTO, and MaT-EDA also achieves impressive many-tasking optimization performance.(c) 2023 Elsevier B.V. All rights reserved.

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# Study of dynamic performance of heat-integrated distillation columns considering the effect of relative volatility of the mixtures

Gutierrez-Guerra, R. Segovia-Hernandez, J. G. Hernandez, S.

In this paper the dynamic performance of Heat-Integrated Distillation Columns (HIDiC) is presented. The dynamic performance was determined for the optimal HIDiC designs optimized previously using a constrained Boltzmann-based estimation of distribution algorithm. Eight close-boiling mixtures, covering a range of relative volatility (alpha) from 1.12 to 2.4, were used as case studies. The dynamic behavior was obtained under open and closed-loop process analysis. The results obtained showed that the HIDiC columns un-dergo worse dynamic performance than their equivalent traditional columns for all case studies. Furthermore, it was notorious that the difference in the dynamic behavior of both configurations kept a relatively uniform trend for most systems. However, a marked dif-ference in the dynamic properties was determined for the mixture close to azeotropic behavior, which experienced a considerably larger control effort.Thus, the novel findings disclosed in this paper show that, although the HIDiC se-quences experienced worse dynamics than the conventional columns, the HIDiC config-urations reached a stable dynamic behavior for all the range of alpha of the mixtures under study. Nevertheless, high control difficulties were particularly determined for the HIDiC configuration used to separate the mixture with alpha close to unity (mixture of xylenes), which in fact is the HIDiC sequence with the best energetic and economic benefits.Hence, the energetic and economic potential of the HIDiC columns is not limited by the dynamic behavior for most case studies analyzed, at least in theoretical terms. However, such potential might be particularly reduced or unharnessed in the separation of the mixture with alpha near the azeotropic behavior due to the dynamics of the HIDiC column for this separation.So, the findings presented in this paper allow to infer that sequential or simultaneous dynamic studies must be achieved along with the optimization of the HIDiC columns to determine the integral performance (energetic, economic and dynamic) of these config-urations.(c) 2023 Institution of Chemical Engineers. Published by Elsevier Ltd. All rights reserved.

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# Numerical Modeling of the Major Temporal Arcade Using BUMDA and Jacobi Polynomials

Soto-Alvarez, Jose Alfredo Cruz-Aceves, Ivan Hernandez-Aguirre, Arturo Hernandez-Gonzalez, Martha Alicia Lopez-Montero, Luis Miguel Solorio-Meza, Sergio Eduardo

Within eye diseases, diabetic retinopathy and retinopathy of prematurity are considered one of the main causes of blindness in adults and children. In order to prevent the disease from reaching such an extreme, a timely diagnosis and effective treatment must be applied. Until now, the way to verify the state of the retina has been to make qualitative observations of fundus images, all carried out by an ophthalmological specialist; however, this is totally restricted to their experience, and some changes in the vascular structure of the retina could be omitted, in addition to the fact that very high resolution images would be needed to be able to detect significant changes. Accordingly, with the help of computational tools, this diagnostic/monitoring process can be improved. This paper presents a novel strategy for the modeling of the MTA by using an estimation of distribution algorithm (EDA) based on the probability density function in order to determine the coefficients and parameters (alpha,beta) of a Jacobi polynomial series. A model using polynomials is the novel aspect of this work since in the literature there are no models of the MTA of this type, in addition to seeking to better cover the profile of the retinal vein. According to the experimental results, the proposed method presents the advantage to achieve superior performance in terms of the mean distance to the closest point (4.34 pixels), and the Hausdorff distance (14.43 pixels) with respect to different state-of-the-art methods of the numerical modeling of the retina, using the DRIVE database of retinal fundus images with a manual delineation of the MTA performed by an specialist.

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# A Radial Hybrid Estimation of Distribution Algorithm for the Truck and Trailer Routing Problem

Perez-Rodriguez, Ricardo Frausto-Hernandez, Sergio

The truck and trailer routing problem (TTRP) has been widely studied under different approaches. This is due to its practical characteristic that makes its research interesting. The TTRP continues to be attractive to developing new evolutionary algorithms. This research details a new estimation of the distribution algorithm coupled with a radial probability function from hydrogen. Continuous values are used in the solution representation, and every value indicates, in a hydrogen atom, the distance between the electron and the core. The key point is to exploit the radial probability distribution to construct offspring and to tackle the drawbacks of the estimation of distribution algorithms. Various instances and numerical experiments are presented to illustrate and validate this novel research. Based on the performance of the proposed scheme, we can make the conclusion that incorporating radial probability distributions helps to improve the estimation of distribution algorithms.

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# An effective hyper heuristic-based memetic algorithm for the distributed assembly permutation flow-shop scheduling problem

Song, Hong-Bo Yang, You-Hong Lin, Jian Ye, Jing-Xuan

In this paper, an effective Hyper Heuristic-based Memetic Algorithm (HHMA) is proposed to solve the Distributed Assembly Permutation Flow-shop Scheduling Problem (DAPFSP) with the objective of minimizing the maximum completion time. A novel searching-stage-based solution representation scheme is presented for both improving the search efficiency and maintaining potential solutions. In the global search stage, Estimation of Distribution Algorithm (EDA) is employed as the high level strategy of EDA-based Hyper Heuristic (EDAHH) to find promising product sequences for further exploitation. Based on the newly found knowledge of critical-products, several efficient Low-Level Heuristics (LLHs) are well designed to construct the LLH set so that the powerful exploration ability of the EDAHH can be guaranteed. A simulated-annealing-like type of acceptance criterion is also embedded into each LLH to avoid premature convergence. Then a Critical-Products-based Referenced Local Search (CP-RLS) method is proposed to improve the quality of superior sub-population by operating on the sub-job-sequences derived from the critical products. The benefit of the presented CP-RLS lies in the excellent exploitation ability with substantially reduced computational cost. Finally, performance evaluation and comparison are both carried out on a benchmark set and the results demonstrate the superiority of HHMA over the state-of-the-art algorithms for the DAPFSP.(c) 2023 Elsevier B.V. All rights reserved.

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# Relational Bayesian Optimization for Permutation

Huang, Bo-Wei Fang, Wen-Zhong Liao, Hsu-Chen Yu, Tian-Li

Relational Bayesian optimization for permutation (RBOP) is a new permutation estimation of distribution algorithm proposed in this paper. RBOP uses binary relations to represent the common property in permutations. Inspired by the Bayesian optimization algorithm, RBOP first builds a Bayesian network using binary relations. Then, RBOP samples genes using the most certain edge in the Bayesian network. In the scenario of black-box optimization, RBOP aims to solve various permutation problems with a limited number of function evaluations. Experiments show that in terms of average relative percentage deviation, RBOP outperforms edge histogram-based sampling algorithm on quadratic assignment problems, permutation flowshop problems and linear ordering problems. Additionally, RBOP also outperforms both node histogram-based sampling algorithm and kernels of Mallows model using Cayley distance on traveling salesman problems, permutation flow shop problems, linear ordering problems and 6 out of 10 instances of quadratic assignment problems.

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# Estimation of Distribution Algorithm with Discrete Hopfield Neural Network for GRAN3SAT Analysis

Gao, Yuan Y. G. Zheng, Chengfeng C. Z. Chen, Ju J. C. Guo, Yueling Y. G.

The Discrete Hopfield Neural Network introduces a G-Type Random 3 Satisfiability logic structure, which can improve the flexibility of the logic structure and meet the requirements of all combinatorial problems. Usually, Exhaustive Search (ES) is regarded as the basic learning algorithm to search the fitness of neurons. To improve the efficiency of the learning algorithm. In this paper, we introduce the Estimation of Distribution Algorithm (EDA) as a learning algorithm for the model. To study the learning mechanism of EDA to improve search efficiency, this study focuses on the impact of EDA on the model under different proportions of literals and evaluates the performance of the model at different phases through evaluation indicators. Analyze the effect of EDA on the synaptic weights and the global solution. From the discussion, it can be found that compared with ES, EDA has a larger search space at the same efficiency, which makes the probability of obtaining satisfactory weights higher, and the proportion of global solutions obtained is higher. Higher proportions of positive literals help to improve the model performance.

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# An Improved Estimation of Distribution Algorithm for Mixed-Integer Nonlinear Programming Problems:

Molina-Perez, Daniel Mezura-Montes, Efren Portilla-Flores, Edgar Alfredo Vega-Alvarado, Eduardo

In a mixed-integer nonlinear programming problem, integer restrictions divide the feasible region into discontinuous feasible parts with different sizes. Meta-heuristic optimization algorithms quickly lose diversity in such scenarios and get trapped in local optima. In this work, we propose an Estimation of Distribution Algorithm (EDA) with two modifications from its previous version (EDA(mv)). The first modification consists in establishing the exploration and exploitation components for the histogram of discrete variables, aimed at improving the performance of the algorithm during the evolution. The second modification is a repulsion operator to overcome the population stagnation in discontinuous parts, so as continuing the search for possible solutions in other regions. From a comparative study on 16 test problems, the individual contribution of each modification was verified. According to statistical test results, the new proposal shows a significantly better performance than the other competitors tested.

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# An Adaptive Evolutionary Multi-Objective Estimation of Distribution Algorithm and Its Application to Multi-UAV Path Planning

Ren, Yuhang Zhang, Liang

This paper concerns the multi-UAV cooperative path planning problem, which is solved by multi-objective optimization and by an adaptive evolutionary multi-objective estimation of distribution algorithm (AEMO-EDA). Since the traditional multi-objective optimization algorithms tend to fall into local optimum solutions when dealing with optimization problems in three dimensions, we suggest an advanced estimation of distribution algorithm. The main idea of this algorithm is to integrate the adaptive deflation of the selection rate, adaptive evolution of the covariance matrix, comprehensive evaluation of individual convergence and diversity, and reference point-based non-dominated ranking. A multi-UAV path planning model involving multi-objective optimization is established, and the designed algorithm is simulated and compared with other three high-dimensional multi-objective optimization algorithms. The results show that the AEMO-EDA proposed in this paper has stronger convergence and wider population distribution diversity in applying to the multi-UAV cooperative path planning model, as well as better global convergence. The algorithm can provide an stable path for each UAV and promote the intelligent operation of the UAV system.

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# How majority-vote crossover and estimation-of-distribution algorithms cope with fitness valleys

Witt, Carsten

The benefits of using crossover in crossing fitness gaps have been studied extensively in evolutionary computation. Recent runtime results show that majority-vote crossover is particularly efficient at optimizing the well-known JUMP benchmark function that includes a fitness gap next to the global optimum. Also estimation-of-distribution algorithms (EDAs), which use an implicit crossover, are much more efficient on JUMP than typical mutation -based algorithms. However, the allowed gap size for polynomial runtimes with EDAs is at most logarithmic in the problem dimension n.In this paper, we investigate variants of the JUMP function where the gap is shifted and appears in the middle of the typical search trajectory. Such gaps can still be overcome efficiently in time O(n log n) by majority-vote crossover and an estimation-of-distribution algorithm, even for gap sizes almost root n. However, if the global optimum is located in the gap instead of the usual all-ones string, majority-vote crossover would nevertheless approach the all-ones string and be highly inefficient. In sharp contrast, an EDA can still find such a shifted optimum efficiently. Thanks to a general property called fair sampling, the EDA will with high probability sample from almost every fitness level of the function, including levels in the gap, and sample the global optimum even though the overall search trajectory points towards the all-ones string. Finally, we derive limits on the gap size allowing efficient runtimes for the EDA.(c) 2022 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

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# An improved differential evolution by hybridizing with estimation-of-distribution algorithm

Li, Yintong Han, Tong Tang, Shangqin Huang, Changqiang Zhou, Huan Wang, Yuan

To fully exploit the strong exploitation of differential evolution (DE) and the strong exploration of the estimation-of-distribution algorithm (EDA), an improved differential evolution by hybridizing the estimation-of-distribution algorithm named IDE-EDA is proposed in the study. Firstly, a novel cooperative evolutionary framework is proposed to hybridize LSHADE-RSP, a state-of-the-art DE variant incorporating DE-based effective improvement strategies, with EDA. Secondly, the dominant individuals generated by LSHADE-RSP are used to establish the probability distribution model for EDA to enhance its exploitation in each generation, and a new control parameter is introduced to balance exploitation and exploration. Then, the use of greed strategy works via EDA to fully retain highquality solutions to the next generation to improve the convergence speed. Finally, the greedy strategy is used to shrink the external archive when its size decreases due to the reduction of the population size. A comparison of IDE-EDA with cutting-edge DE-based and EDA-based variants, including AAVS-EDA, EB-LSHADE, ELSHADE-SPACMA, jSO, LSHADE-RSP, RWGEDA, HSES, and APGSK-IMODE, was implemented to verify its efficiency. The statistical test results on the IEEE CEC 2018 and IEEE CEC 2021 test suites demonstrate that IDE-EDA is an excellent hybrid algorithm. The MATLAB source code of IDE-EDA can be downloaded from https://github.com/Yintong-Li/IDE-EDA. (c) 2022 Elsevier Inc. All rights reserved.

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# Trajectory optimization of space vehicle in rendezvous proximity operation with evolutionary feasibility conserving techniques

Shirazi, Abolfazl Ceberio, Josu Lozano, Jose A.

In this paper, a direct approach is developed for discovering optimal transfer trajectories of close-range rendezvous of satellites considering disturbances in elliptical orbits. The control vector representing the inputs is parameterized via different interpolation methods, and an Estimation of Distribution Algorithm (EDA) that implements mixtures of probability models is presented. To satisfy the terminal conditions, which are represented as non-linear inequality constraints, several feasibility conserving mechanisms associated with learning and sampling methods of the EDAs are proposed, which guarantee the feasibility of the explored solutions. They include a particular implementation of a clustering algorithm, outlier detection, and several heuristic mapping methods. The combination of the proposed operators guides the optimization process in achieving the optimal solution by surfing the regions of the search domain associated with feasible solutions. Numerical simulations confirm that space transfer trajectories with minimum-fuel consumption for the chaser spacecraft can be obtained with terminal condition satisfaction in rendezvous proximity operation.

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# A new knowledge-guided multi-objective optimisation for the multi-AGV dispatching problem in dynamic production environments

Liu, Lei Qu, Ting Thurer, Matthias Ma, Lin Zhang, Zhongfei Yuan, Mingze

The efficiency of material supply for workstations using Automatic Guided Vehicles (AGVs) is largely determined by the performance of the AGV dispatching scheme. This paper proposes a new solution approach for the AGV dispatching problem (AGVDP) for material replenishment in a general manufacturing workshop where workstations are in a matrix layout, and where uncertainty in replenishment time of workstations and stochastic unloading efficiencies of AGVs are dynamic contextual factors. We first extend the literature proposing a mixed integer optimisation model with a delivery satisfaction soft constraint of material orders and two objectives: transportation costs and delivery time deviation. We then develop a new knowledge-guided estimation of distribution algorithm with delivery satisfaction evaluation for solving the model. Our algorithm fuses three knowledge-guided strategies to enhance optimisation capabilities at its respective execution stages. Comprehensive numerical experiments with instances built from a real-world scenario validate the proposed model and algorithm. Results demonstrate that the new algorithm outperforms three popular multi-objective evolutionary algorithms, a discrete version of a recent multi-objective particle swarm optimisation, and a multi-objective estimation of distribution algorithm. Findings of this work provide major implications for workshop management and algorithm design.

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# A Matrix-Cube-Based Estimation of Distribution Algorithm for No-Wait Flow-Shop Scheduling With Sequence-Dependent Setup Times and Release Times

Qian, Bin Zhang, Zi-Qi Hu, Rong Jin, Huai-Ping Yang, Jian-Bo

The no-wait flow-shop scheduling problem (NFSSP) with sequence-dependent setup times (SDSTs) and release times (RTs) is applicable in many areas, such as steel production, food processing, and chemical processing. Estimation of the distribution algorithm (EDA) has recently been recognized as a prominent metaheuristic methodology in the field of evolutionary computation due to its excellent performance of global exploration. In this article, an innovative matrix-cube-based (i.e., 3-D) EDA (MCEDA) is first proposed to minimize the total earliness and tardiness (TET) of the NFSSP with SDSTs and RTs. This problem is NP-hard in the strong sense. First, a 3-D matrix cube is devised to learn the valuable information from promising solutions or excellent individuals. Second, an EDA model or probabilistic model based on the matrix cube and a special sampling method is presented to perform effective exploration in solution space and find promising regions. Third, based on a series of newly defined subneighborhoods, a new local search with both a speed-up scanning method and one search strategy is developed to execute exploitation from promising regions. Fourth, a speed-up evaluation method based on the problem's property is designed to reduce the computational complexity for calculating criterion and accelerate the search process. Owing to the reasonable hybridization of exploration and exploitation, MCEDA can perform very efficient search in solution space. Extensive test results on instances of such a just-in-time problem first show that MCEDA can achieve better solution than state-of-the-art algorithms in obviously less computation time. Additional experiments on instances of various NFSSPs further confirm the efficiency and robustness of MCEDA.

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# An estimation of distribution algorithm with multiple intensification strategies for two-stage hybrid flow-shop scheduling problem with sequence-dependent setup time

Liu, Huan Zhao, Fuqing Wang, Ling Cao, Jie Tang, Jianxin Jonrinaldi

The estimation of distribution algorithm (EDA) has recently emerged as a promising alternative to the traditional evolutionary algorithms for solving combinatorial optimization problems. In this paper, an estimation of distribution algorithm with multiple intensification strategies (EDA-MIS) is proposed to solve a typical kind of hybrid flow-shop scheduling problem. The two-stage heterogeneous hybrid flow-shop scheduling problem is investigated. The sequence-dependent setup time at the first stage is also considered. In the proposed EDA-MIS, the initial population is constructed through the heuristic method and random strategy. An order matrix is established to estimate the probabilistic model of promising solutions. Then the solutions of the algorithm are evolved through the processes of selection, recombination, sampling, and local search. The obtained results indicate that the EDA-MIS provides good solutions in the aspects of solution quality and computational efficiency.

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# An enhanced two phase estimation of distribution algorithm for solving scheduling problem

Hao, Xinchang Tian, Jing Ding, Hui Zhao, Keheng Gen, Mitsuo

Scheduling is one critical issue both in the field of industry engineering and combinatorial optimization research. In order to solve multi-objective scheduling problem with uncertainty, this paper presents a method of enhanced hybrid Estimation of Distribution Algorithm (EDA) with Teaching and Learning-Based Optimization Algorithm (TLBO). First, in order to concentrate their respective advantages, two algorithms of EDA and TLBO are integrated to enhance the capability of both global and local search. Second, scenario-based simulation is adopted to deal with uncertainty, and an adaptive sampling strategy is involved to dynamically adjust the number of scenarios during the evolving process. Third, a problem-specific local search is designed to further improve the optimality of candidate solutions. By comparing with existing algorithms on the benchmark problems of flexible job shop scheduling problem (FJSP), it is to demonstrate that our proposal can obtain better solutions in the aspects of optimality and computational efficiency.

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# Knowledge-Based Reinforcement Learning and Estimation of Distribution Algorithm for Flexible Job Shop Scheduling Problem

Du, Yu Li, Jun-qing Chen, Xiao-long Duan, Pei-yong Pan, Quan-ke

In this study, a flexible job shop scheduling problem with time-of-use electricity price constraint is considered. The problem includes machine processing speed, setup time, idle time, and the transportation time between machines. Both maximum completion time and total electricity price are optimized simultaneously. A hybrid multi-objective optimization algorithm of estimation of distribution algorithm and deep Q-network is proposed to solve this. The processing sequence, machine assignment, and processing speed assignment are all described using a three-dimensional solution representation. Two knowledge-based initialization strategies are designed for better performance. In the estimation of distribution algorithm component, three probability matrices corresponding to solution representation are provided. In the deep Q-network component, 34 state features are selected to describe the scheduling situation, while nine knowledge-based actions are defined to refine the scheduling solution, and the reward based on the two objectives is designed. As the knowledge for initialization and optimization strategies, five properties of the considered problem are proposed. The proposed mixed integer linear programming model of the problem is validated by exact solver CPLEX. The results of the numerical testing on wide-range scale instances show that the proposed hybrid algorithm is efficient and effective at solving the integrated flexible job shop scheduling problem.

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# Surrogate-Assisted Hybrid-Model Estimation of Distribution Algorithm for Mixed-Variable Hyperparameters Optimization in Convolutional Neural Networks

Li, Jian-Yu Zhan, Zhi-Hui Xu, Jin Kwong, Sam Zhang, Jun

The performance of a convolutional neural network (CNN) heavily depends on its hyperparameters. However, finding a suitable hyperparameters configuration is difficult, challenging, and computationally expensive due to three issues, which are 1) the mixed-variable problem of different types of hyperparameters; 2) the large-scale search space of finding optimal hyperparameters; and 3) the expensive computational cost for evaluating candidate hyperparameters configuration. Therefore, this article focuses on these three issues and proposes a novel estimation of distribution algorithm (EDA) for efficient hyperparameters optimization, with three major contributions in the algorithm design. First, a hybrid-model EDA is proposed to efficiently deal with the mixed-variable difficulty. The proposed algorithm uses a mixed-variable encoding scheme to encode the mixed-variable hyperparameters and adopts an adaptive hybrid-model learning (AHL) strategy to efficiently optimize the mixed-variables. Second, an orthogonal initialization (OI) strategy is proposed to efficiently deal with the challenge of large-scale search space. Third, a surrogate-assisted multi-level evaluation (SME) method is proposed to reduce the expensive computational cost. Based on the above, the proposed algorithm is named surrogate-assisted hybrid-model EDA (SHEDA). For experimental studies, the proposed SHEDA is verified on widely used classification benchmark problems, and is compared with various state-of-the-art methods. Moreover, a case study on aortic dissection (AD) diagnosis is carried out to evaluate its performance. Experimental results show that the proposed SHEDA is very effective and efficient for hyperparameters optimization, which can find a satisfactory hyperparameters configuration for the CIFAR10, CIFAR100, and AD diagnosis with only 0.58, 0.97, and 1.18 GPU days, respectively.

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