# Estimation of distribution evolution memetic algorithm for the unrelated parallel-machine green scheduling problem

Xue, Yue Rui, Zhijian Yu, Xianyu Sang, Xiuzhi Liu, Wenjie

With the increasing concern on greenhouse gas emissions, green scheduling decision in the manufacturing factory is gaining more and more attention. This paper addresses the unrelated parallel machine green scheduling problem (UPMGSP) with criteria ofminimizing themakespan and the total carbon emission. To solve the problem, the estimation of distribution evolution memetic algorithm (EDEMA) is proposed. Firstly, based on the minimum machine load first principle, the initialization of the population is proposed. Second, a multi-objective non-dominated sorting approach and the crowding distance are adopted to improve the diversity of individual. Third, to estimate the probability distribution of the solution space, a probability model is presented to enhance the searching ability. Third, five neighbourhood searching operators are designed to handle the job-to-machine assignment. Moreover, the population catastrophe is used to maintain the sustainable diversity of the population. Finally, based on the randomly generated instances of the UPMGSP, extensive computational tests are carried out. The obtained computational results show that the EDEMA has the better searching capability and the better objective value than those of the non-dominated sorting genetic algorithm II and the estimation of distribution evolution algorithm (EDEA) in solving the UPMGSP.

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# CSA-DE/EDA: a Novel Bio-inspired Algorithm for Function Optimization and Segmentation of Brain MR Images

Li, Zhe Xia, Yong Sahli, Hichem

The clonal selection algorithm (CSA), which describes the basic features of an immune response to an antigenic stimulus, has drawn a lot of attention in the biologically inspired computing community, due to its highly adaptive and easy-to-implement nature. Despite many successful applications, CSA still suffers from limited ability to explore the solution space. In this paper, we incorporate the differential evolution (DE) algorithm and the estimation of distribution algorithm (EDA) into CSA, and thus propose a novel bio-inspired algorithm referred to as CSA-DE/EDA. In the proposed algorithm, the hypermutation and receptor editing processes are implemented based on DE and EDA, which provide improved local and global search ability, respectively. We have applied the proposed algorithm to five commonly used benchmark functions for optimization and brain magnetic resonance (MR) image segmentation. Our comparative experimental results show that the proposed CSA-DE/EDA algorithm outperforms several bio-inspired computing techniques. CSA-DE/EDA is a compelling bio-inspired algorithm for optimization tasks.

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# An evolutionary algorithm based hyper-heuristic framework for the set packing problem

Chaurasia, Sachchida Nand Kim, Joong Hoon

In recent years, hyper-heuristics have received massive attention from the research community as an alternative of meta-heuristics. In a hyper-heuristic, generation or selection of an effective heuristic among a pool of heuristics is an important and challenging task in the search process. At each iteration, a suitable heuristic can take the search process toward the global optimal solution. Moreover, some additional factors such as quality and the number of heuristics also affect the performance. In this paper, we propose an evolutionary algorithm based hyper-heuristic framework that incorporates dynamic selection of parameters. To test its generality, effectiveness and robustness, we apply this approach on two different NP-hard problems - set packing problem (SPP) and minimum weight dominating set (MWDS) problem. The proposed approach for the SPP and the MWDS problem has been evaluated respectively on their respective set of benchmark instances. Computational results show that the proposed approach for the SPP and MWDS problem perform much better than their respective state-of-the-art approaches in terms of the solution quality and computational time. (C) 2019 Elsevier Inc. All rights reserved.

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# Large-Scale Estimation of Distribution Algorithms with Adaptive Heavy Tailed Random Projection Ensembles

Sanyang, Momodou L. Kaban, Ata

We present new variants of Estimation of Distribution Algorithms (EDA) for large-scale continuous optimisation that extend and enhance a recently proposed random projection (RP) ensemble based approach. The main novelty here is to depart from the theory of RPs that require (sub-)Gaussian random matrices for norm-preservation, and instead for the purposes of high-dimensional search we propose to employ random matrices with independent and identically distributed entries drawn from a t-distribution. We analytically show that the implicitly resulting high-dimensional covariance of the search distribution is enlarged as a result. Moreover, the extent of this enlargement is controlled by a single parameter, the degree of freedom. For this reason, in the context of optimisation, such heavy tailed random matrices turn out to be preferable over the previously employed (sub-)Gaussians. Based on this observation, we then propose novel covariance adaptation schemes that are able to adapt the degree of freedom parameter during the search, and give rise to a flexible approach to balance exploration versus exploitation. We perform a thorough experimental study on high-dimensional benchmark functions, and provide statistical analyses that demonstrate the state-of-the-art performance of our approach when compared with existing alternatives in problems with 1 000 search variables.

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# Performance Assessment of Non-Gaussian Control Systems Based on Mixture Correntropy

Zhang, Jinfang Wu, Di

The performance assessment of any control system plays a key role in industrial control systems. To meet the real-time requirements of modern control systems, a quick and accurate evaluation of the performance of a system is necessary. In this paper, a performance assessment method of a non-Gaussian control system based on mixture correntropy is proposed for non-Gaussian stochastic systems. Mixture correntropy can solve the problem of minimum entropy translation invariance. When the expected output of a system is unavailable, mixture correntropy combined with the estimation of distribution algorithm (EDA) is used for system identification and noise distribution estimation so as to calculate the benchmark of entropy-based performance assessment. When the expected output of a system is available, the mixture correntropy is directly used as the index to evaluate the performance of the system. To improve the real-time aspect of the performance assessment, an improved EDA is presented to obtain the evaluation index more quickly. For both Gaussian and non-Gaussian systems, the mixture correntropy and the improved identification algorithm are used for system performance assessment, and the results are compared with the minimum entropy index and the probability density function (PDF) curve coincident area index. The comparisons verify the rationality and effectiveness of the correntropy index and the rapidity of the improved EDA algorithm.

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# A hybrid enhanced bat algorithm for the generalized redundancy allocation problem

Xu, Yue Pi, Dechang

A majority of existing works dealing with redundancy allocation problems are based on traditional series-parallel structures. While in many real-life scenarios, the way of connecting subsystems is not limited to a series-only configuration. This paper considers a generalized redundancy allocation problem (GRAP), where the system structure is a more general network. Since the reliability evaluation in GRAPs is a NP-hard problem and the traditional exact symbolic reliability calculation is not suitable, a cellular automata based monte carlo simulation method is implemented in this paper to estimate the system reliability. It is a relatively simple but effective method without knowing the MPs/MCs. Moreover, to deal with GRAPs, a novel discrete bat algorithm is proposed in this paper with a goal of determining an optimal system structure that achieves the minimum cost under several constraints by using redundant components in parallel. Computational complexity of the proposed algorithm is also calculated in this paper. In the end, three experiments are carried out based on ten networks to set parameters, measure the effectiveness of the modifications, and compare with other state-of-the-art algorithms, separately. The reported computational results show that the proposed algorithm is powerful, which is more superior on this sort of problems.

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# Multi-objective search-based software modularization: structural and non-structural features

Jalali, Nafiseh Sadat Izadkhah, Habib Lotfi, Shahriar

Software modularization techniques are employed to understand a software system. The purpose of modularization is to decompose a software system from a source code into meaningful and understandable subsystems (modules). Since modularization of a software system is an NP-hard problem, the modularization quality obtained using evolutionary algorithms is more reasonable than greedy algorithms. All evolutionary algorithms presented for software modularization only consider structural features that are dependent on the syntax of programming languages. For most programming languages, does not exist a tool to extract structural features, so it is not possible to modularize them. To overcome this problem, this paper presents a new multi-objective fitness function, named MOF, which exploits the structural (such as calling dependency and inheritance dependency) and non-structural features (such as semantic contained in the code comments and identifier names), aiming to automatically guide optimization algorithms to find a good decomposition of software systems. To evaluate the performance of this objective function, three optimization strategies, namely global-based search, combining global and local search, and Estimation of Distribution (EoD), are adapted to optimize it. The results on Mozilla Firefox indicate that the proposed algorithm which is based on EoD along with the new MOF function outperforms the algorithms that use structural-based objective functions in guiding the optimization process, in finding more understandable modules.

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# Two-stage hybrid flow shop scheduling on parallel batching machines considering a job-dependent deteriorating effect and non-identical job sizes

Liu, Siwen Pei, Jun Cheng, Hao Liu, Xinbao Pardalos, Panos M.

In this paper, we investigate a specialized two-stage hybrid flow shop scheduling problem with parallel batching machines considering a job-dependent deteriorating effect and non-identical job sizes simultaneously. A novel concept of three-dimensional wasted volume based on the job normal processing time, job size, and job deteriorating rate is first proposed. Some structural properties, as well as a heuristic algorithm, are developed to solve the single parallel batching machine scheduling problem. Since the two-stage hybrid flow shop scheduling problem is NP-hard, a hybrid EDA-DE algorithm combining estimation of distribution algorithm (EDA) and differential evolution (DE) algorithm is proposed to tackle the studied problem. In addition, the Taguchi method of design of experiments (DOE) is implemented to tune the parameters of the EDA-DE. Finally, a series of computational experiments are carried out to compare the performance of the proposed hybrid EDA-DE algorithm and some recent existing algorithms from the literature, and the comparative results validate the effectiveness and efficiency of the proposed algorithm. (C) 2019 Elsevier B.V. All rights reserved.

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# Wavelength Detection Optimization of Fiber Bragg Grating Sensing Networks Based on Distortion Spectrum

Jiang Hao Zhou Qingxu Chen Jing Miao Xiren

To address the problem of difficulty in distortion specttum demodulation of fiber Bragg grating (FBG) based sensing networks, we propose a wavelength demodulation technique based on estimation using a distribution algorithm (EDA). We construct a theoretical function of distortion spectrum based on the super Gaussian function and transform the wavelength detection problem of the distorted FBG sensing network into a function optimization problem. The proposed method is used to demodulate the distortion spectrum of a FBG sensing network through an experiment. The results denote that EDA can not only maintain an average detection accuracy within 1 pm even when the spectrum of FBG is distorted but also quantitatively estimate the distortion degree of FBG. When compared with the traditional peak detection methods, the proposed method can effectively identify the Bragg wavelength from a distortion spectrum. The proposed method provides a novel method to extend the service life and enhance the reliability of an FBG sensor network.

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# Fuzzy Logics as an Integral Part of Evolutionary Algorithms

Thakur, Amit Kannan, Umasankari

Evolutionary algorithms play an important role for solving various optimization problems related to fuel management in reactor physics like core loading pattern optimization (LPO) or refueling. In general, all algorithms make a sample of solution candidates and evaluate the fitness of all candidates, and then the candidates with better fitness value are used to generate the next sample of solution candidates. In optimization algorithms, internal parameters [like population size, weighting factor in estimation of distribution algorithm (EDA) and population size, cross-over rate, etc., in Genetic Algorithm (GA)] have a stiffness problem as the value of these parameters is fixed at the first generation and is not being changed subsequently. However, the flexibility of changing the value of even one internal parameter during the generations will make the algorithm more efficient. In this paper we propose that fuzzy logics can be used in an innovative way to eliminate the stiffness problem related to internal parameters in evolutionary algorithms. As a test case, EDA for initial core LPO of the advanced heavy water reactor is chosen, and the use of fuzzy logics has shown a significant improvement in the algorithm's performance. The appropriate value of weighting factor alpha in EDA has been predicted using fuzzy logics in each generation, and this has resulted in efficiency improvement of the algorithm. The improved methodology is expected to give better performance with other optimization algorithms, such as the GA or Ant Colony Optimization Algorithm, etc.

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# A probability distribution function for investigating node infection and removal times

Tafazzoli, Tala Sadeghiyan, Babak

Considering the important issue of computer infections by worms spread via networks, the theme of source identification has been a prominent research field that aims at investigating infection propagation including acquiring knowledge about the infection and the node removal times when a worm infection happens. This information helps in identifying the patient zero in the worm attack and may be used by computer forensic investigators and network administrators to spot the culprits and to identify related network vulnerabilities. In this paper, we tackle this problem by developing new probabilistic models based on Bayesian networks. We learn a probability distribution to calculate, at every time step, the probability that each node is infected by a scanning worm, using historical data and features extracted from the network and application layers. With the mentioned probability distribution, the node infection status can be inferred using feature values at each time step. We propose a four-step method to investigate the time of infection and removal of each node probabilistically. First, features are extracted and derived from network traffic data. There are no suitable training and test datasets publicly available for our tests; therefore, we developed the training and test datasets using simulations of the Code Red II worm. Second, a prior model is built using training data. Third, the probabilistic model is built by the estimation of distribution algorithm. Fourth, the infection probability of nodes is inferred given the probability distribution and feature values at each time step. It has already been shown that the number of infectious nodes can be probabilistically approximated backward in time through the stochastic Back-to-Origin Markov model. We combine our first model with the prior stochastic Back-to-Origin Markov model to develop our second model. To evaluate our first and second models, we conducted experiments that show that these models can pinpoint the source node and the infection time of nodes with acceptable accuracy. It should be noted that our method could be employed with other propagating worm types including ransomware worms.

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# Fast single individual haplotyping method using GPGPU

Na, Joong Chae Lee, Inbok Rhee, Je-Keun Shin, Soo-Yong

Background: Most bioinformatic tools for next generation sequencing (NGS) data are computationally intensive, requiring a large amount of computational power for processing and analysis. Here the utility of graphic processing units (GPUs) for NGS data computation is assessed.

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# Unbiasedness of estimation-of-distribution algorithms

Friedrich, Tobias Koetzing, Timo Krejca, Martin S.

In the context of black-box optimization, black-box complexity is used for understanding the inherent difficulty of a given optimization problem. Central to our understanding of nature-inspired search heuristics in this context is the notion of unbiasedness. Specialized black-box complexities have been developed in order to better understand the limitations of these heuristics - especially of (population-based) evolutionary algorithms (EAs). In contrast to this, we focus on a model for algorithms explicitly maintaining a probability distribution over the search space: so-called estimation-of-distribution algorithms (EDAs). We consider the recently introduced n-Bernoulli-lambda-EDA framework, which subsumes, for example, the commonly known EDAs PBIL, UMDA, lambda-MMAS(IB), and cGA. We show that an n-Bernoulli-lambda-EDA is unbiased if and only if its probability distribution satisfies a certain invariance property under isometric automorphisms of [0, 1](n). By restricting how an n-Bernoulli-lambda-EDA can perform an update, in a way common to many examples, we derive conciser characterizations, which are easy to verify. We demonstrate this by showing that our examples above are all unbiased. (C) 2018 Elsevier B.V. All rights reserved.

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# A parallel refined probabilistic approach for QoS-aware service composition

Wang, Hongbing Peng, Shunshun Yu, Qi

Service composition integrates existing online services to provide a value-added service. With the rapid growth of web services with similar functionalities, Quality of Service (QoS) has emerged as an important quantitative criterion on non-functional aspects. The optimization of QoS-aware service composition, depending on different aggregated QoS attributes has attracted significant attention. The dynamic nature of QoS-aware service composition adds further challenges to the optimization problem. Most existing approaches ignore the diversity of solutions, which have the potential to provide alternative compositions when changes occur. A few works only partially explore the search space and do not consider the optimality of solutions and the computational cost concurrently. To address these issues, we propose a novel reactive approach, called MrEDA, which integrates the estimation of distribution algorithm (EDA), restricted boltzmann machine (RBM), and multi-agent technology. It constructs a refined probabilistic model to diversify alternative solutions and guide the search by adaptively capturing the promising information of a service composition. Meanwhile, multiple agents make use of a flexible parallelism with distinct explorations and adaptive sampling to improve the global optimization and speed up the optimization. The effectiveness and efficiency of our approach for adaptive service composition is validated through an extensive experimental evaluation. (C) 2019 Elsevier B.V. All rights reserved.

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# Estimation of Distribution Algorithm for Joint Resource Management in D2D Communication

Ahmad, Mushtaq Naeem, Muhammad Iqbal, Muhammad

Device to device (D2D) communication technique is one of the established means to enhance data rate in next generation wireless systems. Use of same resource of cellular users by D2D pairs creates interference problem among users. Simultaneous resource management and mode selection in emerging cellular networks having D2D capabilities can surely improve overall system throughput. This work addresses the problem of overall throughput maximization of emerging cellular networks while ensuring the power and interference constraints. The joint resource management problem is NP-Hard and is classified as mixed integer non-linear constraint optimization problem. Due to the fact that, the computational complexity of the system increases exponentially with the increase in users, it is almost impossible to find sub-optimal solution in polynomial time using greedy approach. Therefore, this paper applies evolutionary technique, like estimation of distribution algorithm which has the potential to address the complex problems having combinatorial nature such as joint resource management strategy in D2D. Near optimal solution convergence is achieved by the algorithm with minimal number of iterations. Simulation results show the effectiveness of the proposed approach as compared to other algorithms.

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# Balancing exploration and exploitation in multiobjective evolutionary optimization

Zhang, Hu Sun, Jianyong Liu, Tonglin Zhang, Ke Zhang, Qingfu

The tradeoff between exploration and exploitation is critical to the performance of an evolutionary algorithm. Different levels of exploration-exploitation tradeoff are required at different evolutionary stages for achieving a satisfactory performance of an evolutionary algorithm. In this paper, we propose a novel survival analysis method to intelligently guide the maintenance of the exploration-exploitation tradeoff in multiobjective evolutionary algorithms. The survival analysis stems from a deep understanding of the evolutionary search procedure. Through survival analysis, an indicator is derived, which is used to guide the adoption of appropriate recombination operators, based on the assumption that the roles of these operators in terms of their capabilities on exploration-exploitation can be asserted. In the developed algorithm, a differential evolution recombination operator and a new sampling strategy are hybridized. Empirical comparison with five well-known multiobjective evolutionary algorithms on a number of test instances with complex Pareto sets and Pareto fronts indicates the effectiveness and superiority of the developed algorithm in terms of commonly-used performance metrics on these test instances. (C) 2019 Elsevier Inc. All rights reserved.

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# A Hybrid Metaheuristic of Integrating Estimation of Distribution Algorithm with Tabu Search for the Max-Mean Dispersion Problem

Nijimbere, Dieudonne Zhao, Songzheng Liu, Haichao Peng, Bo Zhang, Aijun

This paper presents a hybrid metaheuristic that combines estimation of distribution algorithm with tabu search (EDA-TS) for solving the max-mean dispersion problem. The proposed EDA-TS algorithm essentially alternates between an EDA procedure for search diversification and a tabu search procedure for search intensification. The designed EDA procedure maintains an elite set of high quality solutions, based on which a conditional preference probability model is built for generating new diversified solutions. The tabu search procedure uses a fast 1-flip move operator for solution improvement. Experimental results on benchmark instances with variables ranging from 500 to 5000 disclose that our EDA-TS algorithm competes favorably with state-of-the-art algorithms in the literature. Additional analysis on the parameter sensitivity and the merit of the EDA procedure as well as the search balance between intensification and diversification sheds light on the effectiveness of the algorithm.

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# A Pareto-Based Estimation of Distribution Algorithm for Solving Multiobjective Distributed No-Wait Flow-Shop Scheduling Problem With Sequence-Dependent Setup Time

Shao, Weishi Pi, Dechang Shao, Zhongshi

Influenced by the economic globalization, the distributed manufacturing has been a common production mode. This paper considers a multiobjective distributed no-wait flowshop scheduling problem with sequence-dependent setup time (MDNWFSP-SDST). This scheduling problem exists in many real productions such as baker production, parallel computer system, and surgery scheduling. The performance criteria are the makespan and the total weight tardiness. In the MDNWFSP-SDST, several identical factories are considered with the related flow-shop scheduling problem with no-wait constraints. For solving the MDNWFSP-SDST, a Pareto-based estimation of distribution algorithm (PEDA) is presented. Three probabilistic models including the probability of jobs in empty factory, two jobs in the same factory, and the adjacent jobs are constructed. The PWQ heuristic is extended to the distributed environment to generate initial individuals. A sampling method with the referenced template is presented to generate offspring individuals. Several multiobjective neighborhood search methods are developed to optimize the quality of solutions. The comparison results show that the PEDA obviously outperforms other considered multiobjective optimization algorithms for addressing MDNWFSP-SDST.

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# A latent space-based estimation of distribution algorithm for large-scale global optimization

Dong, Wenyong Wang, Yufeng Zhou, Mengchu

Large-scale global optimization problems (LSGOs) have received considerable attention in the field of meta-heuristic algorithms. Estimation of distribution algorithms (EDAs) are a major branch of meta-heuristic algorithms. However, how to effectively build the probabilistic model for EDA in high dimensions is confronted with obstacle, making them less attractive due to the large computational requirements. To overcome the shortcomings of EDAs, this paper proposed a latent space-based EDA (LS-EDA), which transforms the multivariate probabilistic model of Gaussian-based EDA into its principal component latent subspace with lower dimensionality. LS-EDA can efficiently reduce the complexity of EDA while maintaining its probability model without losing key information to scale up its performance for LSGOs. When the original dimensions are projected to the latent subspace, those dimensions with larger projected value make more contribution to the optimization process. LS-EDA can also help recognize and understand the problem structure, especially for black-box optimization problems. Due to dimensionality reduction, its computational budget and population size can be effectively reduced while its performance is highly competitive in comparison with the state-of-the-art meta-heuristic algorithms for LSGOs. In order to understand the strengths and weaknesses of LS-EDA, we have carried out extensive computational studies. Our results revealed LS-EDA outperforms the others on the benchmark functions with overlap and nonseparate variables.

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# A novel approach for protein structure prediction based on an estimation of distribution algorithm

Morshedian, Amir Razmara, Jafar Lotfi, Shahriar

Protein structure prediction is one of the major challenges in structural biology and has wide potential applications in biotechnology. However, the problem is faced with a difficult optimization requirement with particularly complex energy landscapes. The current article aims to present a novel approach namely AHEDA as an evolutionary-based solution to overcome the problem. AHEDA uses the hydrophobic-polar model to develop a robust and efficient evolutionary-based algorithm for protein structure prediction. The method utilizes an integrated estimation of distribution algorithm that attempts to optimize the search process and prevent the destruction of structural blocks. It also uses a stochastic local search to improve its accuracy. Based on a comprehensive comparison with other existing methods on 24 widely used benchmarks, AHEDA was shown to generate highly accurate predictions compared to the other similar methods.

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# An efficient estimation of distribution algorithm with rank-one modification and population reduction

Liang, Yongsheng Ren, Zhigang He, Miao Wang, Lin Cao, Jianfu Chen, An Pang, Bei

As a type of model-based metaheuristic, estimation of distribution algorithms (EDAs) show certain advantages over other metaheuristics by using statistical learning method to estimate the distribution of promising solutions. However, the commonly-used Gaussian EDAs (GEDAs) usually suffer from premature convergence that severely limits their efficiency. In this paper, we first attempt to enhance the performance of GEDA by improving its model estimation method. The new estimation method shifts the weighted mean of high-quality solutions towards the fitness improvement direction and estimates the covariance matrix by taking the shifted mean as the center. Theoretical analyses show that the new covariance matrix is essentially a rank-one modification (R1M) of the original one. It could effectively adjust both the search scope and the search direction of GEDA, and thus improving the search efficiency. Furthermore, considering the importance of the population size tuning in GEDA, we develop a population reduction (PR) strategy which linearly reduces the population size throughout the evolution. By this means, the exploration and exploitation ability of GEDA could be balanced better in different search stages and a more proper utilization of limited computation resource can be achieved. Combining GEDA with the R1M and PR strategies, a novel EDA variant named EDA-R1M-PR is developed. The performance of EDA-R1M-PR was comprehensively evaluated and compared with that of several state-of-the-art evolutionary algorithms. Experimental results indicate that the R1M and PR strategies effectively enhance the global optimization ability of GEDA and the resultant EDA-R1M-PR significantly outperforms its competitors on a set of benchmark functions.

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# An EDA for the 2D knapsack problem with guillotine constraint

Borgulya, Istvan

In this paper we present an evolutionary heuristic for the 2D knapsack problem with guillotine constraint. In this problem we have a set of rectangles and there is a profit for each rectangle. The goal is to cut a subset of rectangles without overlap from a rectangular strip of width W and height H, so that the total profit of the rectangles from the subset is maximal. The sides of the rectangles are parallel to the strip sides and every cutting is restricted by orthogonal guillotine-cuts. A guillotine-cut is parallel to the horizontal or vertical side of the strip and cuts the strip into two separated rectangular strips. Our algorithm is an estimation of distribution algorithm (EDA), where recombination and mutation evolutionary operators are replaced by probability estimation and sampling techniques. Our EDA works with two probability models. It improves the quality of the solutions with local search procedures. The algorithm was tested on well-known benchmark instances from the literature.

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# An Enhanced Estimation of Distribution Algorithm for Energy-Efficient Job-Shop Scheduling Problems with Transportation Constraints

Dai, Min Zhang, Ziwei Giret, Adriana Salido, Miguel A.

Nowadays, the manufacturing industry faces the challenge of reducing energy consumption and the associated environmental impacts. Production scheduling is an effective approach for energy-savings management. During the entire workshop production process, both the processing and transportation operations consume large amounts of energy. To reduce energy consumption, an energy-efficient job-shop scheduling problem (EJSP) with transportation constraints was proposed in this paper. First, a mixed-integer programming model was established to minimize both the comprehensive energy consumption and makespan in the EJSP. Then, an enhanced estimation of distribution algorithm (EEDA) was developed to solve the problem. In the proposed algorithm, an estimation of distribution algorithm was employed to perform the global search and an improved simulated annealing algorithm was designed to perform the local search. Finally, numerical experiments were implemented to analyze the performance of the EEDA. The results showed that the EEDA is a promising approach and that it can solve EJSP effectively and efficiently.

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# An elitist nondominated sorting hybrid algorithm for multi-objective flexible job-shop scheduling problem with sequence-dependent setups

Li, Z. C. Qian, B. Hu, R. Chang, L. L. Yang, J. B.

In this paper, an elitist nondominated sorting hybrid algorithm, namely ENSHA, is proposed to solve the multi-objective flexible job-shop scheduling problem (MOFJSSP) with sequence-dependent setup times/costs (MOFJSSP\_SDST/C). The objectives to be minimized are the maximal completion time (i.e., makespan) and the total setup costs (TSC). The makespan is an efficiency-focused objective whereas the TSC is an economic focused one. Existing works mainly consider the efficiency-focused multiple criteria. The main highlights of this paper are threefold, i.e., the operation-based sequence model, the problem-dependent job assignment rules and the novel evolutionary framework of ENSHA. For the operation-based sequence model, this is the first time that the sequence model of MOFJSSPs has been proposed and the TSC has been treated as an independent objective in MOFJSSPs. For the job assignment rules, the solution representation is first proposed, and then three job assignment rules are specifically designed to decode solutions or sequences into feasible scheduling schemes. For the novel evolutionary framework, it works with two populations, i.e., the main population (MP) and the auxiliary population (AP). First, ENSHA adopts the elitist nondominated sorting method for evolving MP to maintain high-quality solutions regarding both the convergence and diversity. Next, a machine learning strategy based on the estimation of distribution algorithm (EDA) is proposed to learn the valuable information from nondominated solutions in MP for building a probabilistic model. This model is then used to generate the offspring of AP. Furthermore, a simple yet effective cooperation-based refinement mechanism is raised to combine MP and AP, so as to generate MP of the next generation. Finally, experimental results on 39 benchmark instances and a real-life case study demonstrate the effectiveness and application values of the proposed ENSHA. (C) 2019 Elsevier B.V. All rights reserved.

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# Dynamic deployment optimization of near space communication system using a novel estimation of distribution algorithm

Wang, Zhao Gong, Maoguo

A robust deployment of the airship platforms is crucial to the performance of the Near Space Communication System (NSCS) in the dynamic environment. In this paper, a multiobjective NSCS deployment optimization model with multi-phased periodic user distribution is proposed. To optimize this model, we propose a local incremental estimation of distribution algorithm with an asymmetrical domination relationship within the multiobjective evolutionary algorithm based on decomposition framework. The conflict between the selection mechanism and the domination relationship is also analyzed theoretically for the first time. To obtain robust solutions under this conflict, the local distribution information of a certain subproblem within several generations is encompassed into a local incremental distribution model. As a generalized form of the existing domination relationship, an asymmetrical domination relationship (ADR), which treats the current and past objective values differently, is proposed to select robust solutions. The proposed algorithm is also tested on four designed problems compared with another four popular algorithms and proves its superiority. Some important parameters are also investigated in the experiments and some guidelines on tuning these parameters are given as well. (C) 2019 Elsevier B.V. All rights reserved.

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# Wavelength Demodulation of a Spectrally Overlapped Fiber Bragg Grating Sensor Network Based on Peak Match Estimation of Distribution Algorithm

Chen Jing Lin Ya-ting Zhou Qing-xu Jiang Hao

In order to address the wavelength demodulation of the overlapped spectra for the fiber Bragg grating sensor networks with limited source bandwidth, a wavelength demodulation method based on peak match estimation of distribution algorithm is proposed. The proposed method transforms the wavelength demodulation problem into a function optimization problem, where the optimization model is constructed through minimizing the difference between the theoretical spectra and the overlapped spectra. The peak match estimation of distribution algorithm is applied to solve the optimization model and obtain the sensing data for each fiber Bragg grating. Estimation of distribution algorithmutilizes the Gaussian mixture model to build probability distribution of the solution space for fiber Bragg grating sensor network, and the probability model can generate new individuals in the evolution of estimation of distribution algorithm. The peak match operator is introduced into the estimation of distribution algorithm to avoid the mismatch of the peak values of fiber Bragg gratings and obtain the final optimal solution. The experiments are conducted under different numbers of fiber Bragg grating sensor network using the proposed method. The experimental results demonstrate that the proposed method yields the mean errors within 10 pm for the large scale fiber Bragg grating sensor network even when the spectra of fiber Bragg gratings are completely overlapped. Compared with other demodulation methods, accuracy of the proposed method is hi g her, and it can well solve the wavelength demodulation problem when the spectra of fiber Bragg gratings within the network are partially or completely overlapped. The proposed method provides a new way to improve the multiplexing capability of fiber Bragg grating sensor networks.

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# A hybrid multi-objective EDA for robust resource constraint project scheduling with uncertainty

Tian, Jing Hao, Xinchang Gen, Mitsuo

This paper presents a multi-phased algorithm hybrid genetic algorithm and multi-objective Markov network based Estimation of Distribution Algorithm (robust hGMEDA), to solve the robust scheduling problem for resource constrained scheduling problem (RCSP) with time uncertainty. Firstly, for modelling, two kinds of robust measures on time-based-robust and capacity-based-robust are introduced to evaluate the robustness of scheduling solutions. Secondly, for solving methodology, within the multi stage architecture based on sequential co-evolutionary paradigm, genetic algorithm (GA) is used to find feasible solution for sequencing sub-problem, and multi-objective Markov network based Estimation of Distribution Algorithm (MMEDA) is adopted to model the interrelation for resource allocation and calculate the Pareto set with the scenario based approach. Next, the alternative solutions are checked by the chance constraints by using scenario-based simulation. Moreover, one problem-specific local search with considering both makespan and robustness is designed to improve the solution quality. The implementation results provide practical support that experiment results based on a benchmark "Project Scheduling Problems Library" (PSPLIB) and comparisons demonstrate that our approach is highly effective and tolerant of uncertainty.

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# A hybrid estimation of distribution algorithm for the vehicle routing problem with time windows

Perez-Rodriguez, Ricardo Hernandez-Aguirre, Arturo

The Vehicle Routing Problem (VRP) seeks to find minimum-travel routes for a set of vehicles. The routes contain a set of customers with known demands. Each vehicle departs and arrives at the same depot. In the vehicle routing problem with time windows (VRPTW), each vehicle has to arrive in a specific time window with each customer and also each vehicle has to return to the depot before a due time. In this research, the use of an estimation of distribution algorithm to solve the problem is proposed. The algorithm uses the generalized Mallows distribution as a probability model to describe the distribution of the solution space. Homberger-Gehring's instances are used as input and test parameters in order to show that the modification of the generalized Mallows distribution mentioned is able to produce competitive sequences for the VRPTW against some other estimation of distribution algorithms used in permutation-based optimization problems.

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# Distance-oriented hierarchical control and ecological driving strategy for HEVs

Zhang, Bowen Lim, Hansang Xu, Shengyao Su, Wencong

Hybrid electric vehicles (HEVs) provide a promising alternative to conventional engine-powered vehicles, with less emission and better fuel economy. This study proposes a hierarchical control for a power-split HEV over a driving cycle, featuring pre-trip optimisation and en-route speed adaption. Constraints including vehicle powertrain boundaries, road gradients, and speed limits, are taken into consideration. In the first stage, the HEV operating conditions, including the optimal vehicle SOC, speed profiles, and total driving time, are generated for the entire trip before departure. Based on the pre-trip results, the second stage adapts the vehicle speed for a short horizon when driving, while taking the safety spacing to the preceding vehicle into consideration, which acts as an indicator of actual traffic conditions and guarantees safe driving. Both optimisations are conducted under the distance domain for realising localisation in the optimal speed profile due to frequent changes in traffic conditions. An estimation of distribution algorithm is used to run the simulation so that the feasibility, robustness, and effectiveness of the proposed hierarchical control can be demonstrated.

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# Visual Analysis Scenarios for Understanding Evolutionary Computational Techniques' Behavior

Meiguins, Aruanda Santos, Yuri Santos, Diego Meiguins, Bianchi Morais, Jefferson

Machine learning algorithms are used in many applications nowadays. Sometimes, we need to describe how the decision models created output, and this may not be an easy task. Information visualization (InfoVis) techniques (e.g., TreeMap, parallel coordinates, etc.) can be used for creating scenarios that visually describe the behavior of those models. Thus, InfoVis scenarios were used to analyze the evolutionary process of a tool named AutoClustering, which generates density-based clustering algorithms automatically for a given dataset using the EDA (estimation-of-distribution algorithm) evolutionary technique. Some scenarios were about fitness and population evolution (clustering algorithms) over time, algorithm parameters, the occurrence of the individual, and others. The analysis of those scenarios could lead to the development of better parameters for the AutoClustering tool and algorithms and thus have a direct impact on the processing time and quality of the generated algorithms.

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# An Adaptive Estimation of Distribution Algorithm for Multipolicy Insurance Investment Planning

Shi, Wen Chen, Wei-Neng Lin, Ying Gu, Tianlong Kwong, Sam Zhang, Jun

Insurance has been increasingly realized as an important way of investment and risk aversion. Fruitful insurance products are launched by insurers, but there is little research on how to make a proper insurance investment plan for a specific policyholder given different kinds of policies. In this paper, we aim to propose a practical approach to multipolicy insurance investment planning with a data-driven model and an estimation of distribution algorithm (EDA). First, by making use of the insurance data accumulated in the modern financial market, an optimization model about how to choose endowment and hospitalization policies is built to maximize the yearly profit of insurance investment. With the model parameters set according to the real data from insurance market, the resulting plan is practical and individualized. Second, as the optimal solution cannot be achieved by mathematical deduction under this data-driven model, an EDA is introduced. To adapt the EDA for the considered problem, the proposed EDA is mixed with both the continuous and discrete probability distribution models to handle different kinds of variables. In addition, an adaptive scheme for choosing suitable distribution models and an efficient constraint handling strategy are proposed. Experiments under different conditions confirm the effectiveness and efficiency of the proposed model and method.

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# A combination method using evolutionary algorithms in initial orbit determination for too short arc

Li, Xin-Ran Wang, Xin Xiong, Yong-qing

With the combination of two evolutionary algorithms EDA and DE, a new method of initial orbit determination for satellites based on ground-based too-short-arc is established. Compared with other algorithms, the proposed method focuses on the most densely populated region in the solution space rather than the individual with best fitness value. Both the global information and local information are well fused in the search of optimum. In the method (a, e, M) are treated as variables of the optimization, and the optimization procedure is carried out as a two-stage hierarchical optimization problem which has three variables for each stage. Kernel density estimation is applied to build the probability distribution model without any assumptions of the specified distribution, accompanied by handling semi-major axis and eccentricity as a pair of dependent variables in the construction of the probability for the correlation between them in the practice. Numerical experiments with real ground-based observations show that the proposed method is applicable to too-short-arc with even 3 s, and the result of bias in several kilometers can be achieved with 5 '' error added to angular measurements. (C) 2018 COSPAR. Published by Elsevier Ltd. All rights reserved.

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# BlueCollar: Optimizing Worker Paths on Factory Shop Floors with Visual Analytics

Herr, Dominik Grund, Sebastian Ertl, Thomas

The optimization of a factory's productivity regarding quality and efficiency is an important task in the manufacturing domain. To optimize the productivity, production lines are optimized to have short transportation paths and short processing times at the stations that process intermediate components or the final product. A factory's layout is a key factor in this optimization aspect. This optimization mostly comprises the machine tools' positions with respect to places where supply goods are being delivered and other tools are stationed, often neglecting the paths that workers need to take at the shop floor. This impairs a factory's productivity, as machines may need to wait for workers, who operated another machine and are still on the way due to the long distance between the machines. In this work, we present BlueCollar, a visual analytics approach that supports layout planners to explore and optimize existing factory layouts regarding the paths taken by workers. Planners can visually inspect the paths that workers need to take based on their work schedule and the factory's layout. An estimation of distribution algorithm supports them in choosing which layout elements, e.g., shared tool caches, to relocate. Its intermediate and final results are used to provide visual cues for suitable relocation areas, and to suggest new layouts automatically. We demonstrate our approach through an application scenario based on a realistic prototype layout provided by an external company.

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# Research Survey and Application on Ground Holding Policy

Yan, Yongjie Zhang, Yan Tian, Jing

This paper introduces the origination, concept of ground holding policy and research literature review firstly. Next, three types of models are built for single airport ground holding problem (SAGHP), multi airport ground holding problem (MAGHP) and dynamic single airport ground holding problem (dSAGHP). For solving algorithms, two conventional methods of First Come First Served (FCFS) and dynamic Sequencing Window are explained briefly, then one heuristic algorithm named Estimation of Distribution Algorithm (EDA) is illustrated in detail to solve the ground delay problems, including problem-specific modeling, probability learning and new solutions sampling. Finally, experiment results based on simulation instances and discussions are given.

[Paper](https://www.webofscience.com/api/gateway?GWVersion=2&SrcApp=edas&SrcAuth=WosAPI&KeyUT=WOS:000618065500129&DestLinkType=FullRecord&DestApp=WOS_CPL)

# A Double Learning Models-Based Multi-Objective Estimation of Distribution Algorithm

Lin, Yanyan Liu, Han Jiang, Qiaoyong

The recently developed regularity model-based multi-objective estimation of distribution algorithm (RM-MEDA) and inverse models-based multi-objective evolutionary algorithm (IM-MOEA) have been shown to be two effective methods for solving some complex multi-objective optimization problems (MOPs). However, RM-MEDA and IM-MOEA are still challenged when solving MOPs with many local Pareto fronts, and usually generate poor solutions when the population has no obvious regularity. In order to overcome these limits, an ensemble of RM-MEDA and IM-MOEA, denoted as RM-IM-EDA, is proposed in this paper. This ensemble is based on a dynamic mixture of the sampling in the decision space by the regularity-based learning model and the sampling in the objective space using the inverse learning models. In addition, a sequence-based deterministic initialization method is introduced to identify the properties of fitness landscape. The objective behind this scheme is to reduce the probability of sinking into the local Pareto optimum. For the comparison purposes, the proposed RM-IM-EDA is tested on 32 benchmark problems. Experiment results statistically affirm the efficiency of the proposed approach to obtain better results compared with each individual algorithm and other four state-of-the-art MEDAs.

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# Intelligent Path Planning for AUVs in Dynamic Environments: An EDA-Based Learning Fixed Height Histogram Approach

Liu, Run-Dong Chen, Zong-Gan Wang, Zi-Jia Zhan, Zhi-Hui

Autonomous underwater vehicles (AUVs) are robots that require path planning to complete missions in different kinds of underwater environments. The goal of path planning is to find a feasible path from the start-point to the target-point in a given environment. In most practical applications, environments have dynamic factors, such as ocean flows and moving obstacles, which make the AUV path planning more challenging. This paper proposes an estimation of distribution algorithm (EDA) based approach, termed as learning fixed-height histogram (LFHH) to solve path planning problems for AUVs in dynamic environment. The LFHH uses a learning transformation strategy (LTS) to improve its accuracy and convergence speed. Besides, a smooth method is employed to accelerate the speed of finding feasible paths. Moreover, a planning window is adopted to help handle dynamic factors. LFHH is tested in both complex 2-D and 3-D environments with time-variant dynamic factors, and experimental results validate the effectiveness of LFHH.

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# Evolutionary Estimation of Distribution Algorithm for Agricultural Routing Planning in Field Logistics

Utamima, Amalia Reiners, Torsten Ansaripoor, Amir H.

Agricultural Routing Planning (ARP), a problem in field logistics, has the objective to minimize the headland distance used by machines when performing agricultural tasks. This study gathers for its datasets the data for several fields obtained from previous research. The Estimation of Distribution Algorithm (EDA) is an algorithm that employs a probabilistic model to produce candidate solutions. This paper extends the EDA to become the Evolutionary EDA that combines a general EDA, a neighborhood search, and an elitism technique. Evolutionary EDA is tested on the optimization of ARP. The experimental results show that Evolutionary EDA can get the same or outperform the solutions generated by previously applied algorithms on ARP problems. (C) 2019 The Authors. Published by Elsevier B.V.

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# An Evolutionary Algorithm Based Hyper-heuristic for the Set Packing Problem

Chaurasia, Sachchida Nand Jung, Donghwi Lee, Ho Min Kim, Joong Hoon

Utilizing knowledge of the problem of interest and lessons learned from solving similar problemswould help to find the final optimal solution of better quality. A hyper-heuristic algorithm is to gain an advantage of such process. In this paper, we present an evolutionary algorithm based hyper-heuristic framework for solving the set packing problem (SPP). The SPP is a typicalNP-hard problem. The hyper-heuristic is comprising of high level and low level. The higher level is mainly engaged in generating or constructing a heuristic. An evolutionary algorithm with guided mutation (EA/G) is employed at the high level. Whereas a set of problem-independent and problem-specific heuristics, called low level heuristics, are employed at the low level of hyper-heuristic. EA/G is recently added to the class of the evolutionary algorithms that try to utilize the complementary characteristics of genetic algorithms (GAs) and estimation of distribution algorithms (EDAs) to generate new offspring. In EA/G, the guided mutation operator generates an offspring by sampling the probability vector. The proposed approach is compared with the state-of-the-art approaches reported in the literature. The computational results show the effectiveness of the proposed approach.

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# A Mathematical Analysis of EDAs with Distance-based Exponential Models

Unanue, Imanol Merino, Maria Lozano, Jose A.

Estimation of Distribution Algorithms have been successfully used for solving many combinatorial optimization problems. One type of problems in which Estimation of Distribution Algorithms have presented strong competitive results are permutation-based combinatorial optimization problems. In this case, the algorithms use probabilistic models specifically designed for codifying probability distributions over permutation spaces. One class of these probability models is distance-based exponential models, and one example of this class is the Mallows model. In spite of the practical success, the theoretical analysis of Estimation of Distribution Algorithms for permutation-based combinatorial optimization problems has not been extensively developed. With this motivation, this paper presents a first mathematical analysis of the convergence behavior of Estimation of Distribution Algorithms based on the Mallows model by using an infinite population to associate a dynamical system to the algorithm. Several scenarios, with different fitness functions and initial probability distributions of increasing complexity, are analyzed obtaining unexpected results in some cases.

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# EDA with Hamming Distance for Consumption-Loan Planning in Experimental Economics

Orito, Yukiko Kashima, Tomoko

For the consumption-loan planning in the experimental economics, this paper proposes the EDA (Estimation of Distribution Algorithm) using Hamming distance in order to avoid convergence on a local solution. The EDA with Hamming distance restrains the quantitative change in a solution structure on the processes of EDA.

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# Application of Estimation of Distribution Algorithm for Feature Selection

Ayodele, Mayowa

Feature selection is a machine learning concept that entails selecting relevant features while eliminating irrelevant and redundant features. This process helps to speed up learning. In this paper, an Estimation of Distribution Algorithm (EDA) is applied to a feature selection problem originating from a legal business. The EDA was able to generate a realistic solution to the real-world problem.

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# Hybrid Estimation of Distribution Algorithm for solving a Resource Level Allocation Problem in a Legal Business

Ayodele, Mayowa Papamichail, K. Nadia Gallagher, Geraldine Buckley, Darren

Resource level allocation entails assigning execution times to a set of resource levels required to complete a task. This is an important problem, particularly in the services sector. We consider a real-world variant of this problem originating from a legal business. The objective considered is the maximisation of damages savings.

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# Approaching the Quadratic Assignment Problem with Kernels of Mallows Models under the Hamming Distance

Arza, Etor Ceberio, Josu Perez, Aritz Irurozki, Ekhine

Abstract no encontrado

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# Optimizing Permutation-Based Problems With a Discrete Vine-Copula as a Model for EDA

Cheriet, Abdelhakim Santana, Roberto

In this paper, we introduce a copula-based EDA that uses a Discrete Vine-Copula (DVC) model. This model is particularly suited to represent distributions in the permutation representation. To demonstrate the effectiveness of the proposed Discrete-Vine-Copula based EDAs (DVCEDA), we perform a set of experiments on instances of the known TSP problems. The results obtained are promising to extend the work on other class of problems.

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# An Exponential Lower Bound for the Runtime of the Compact Genetic Algorithm on Jump Functions

Doerr, Benjamin

In the first runtime analysis of an estimation-of-distribution algorithm (EDA) on the multimodal jump function class, Hasenohrl and Sutton (GECCO 2018) proved that the runtime of the compact genetic algorithm with suitable parameter choice on jump functions with high probability is at most polynomial (in the dimension) if the jump size is at most logarithmic (in the dimension), and is at most exponential in the jump size if the jump size is super-logarithmic. The exponential runtime guarantee was achieved with a hypothetical population size that is also exponential in the jump size. Consequently, this setting cannot lead to a better runtime.

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# Cash flow prediction using artificial neural network and GA-EDA optimization

Amalnik, Mohsen Sadegh Iranmanesh, Hossein Asghari, Atabak Mollajan, Ali Fadakar, Vahed Daneshazarian, Reza

Cash flow models are one of the spotlights for evaluating a project. The actual data should be modeled then it could be used for the prediction process. In this paper, 996 airplane maintenance basis data are used as a database, and 119 similar data are chosen after clustering. The project is divided into 20 equal periods and first three periods are used for simulating the next point. The predicted data for each point is achieved by using of previous points from the beginning. The model is based on artificial neural network, and it is trained by three algorithms which are Genetic Algorithm (GA), Estimation of Distribution Algorithm (EDA), and hybrid GA-EDA method. Two dynamic ratios are used which are dividing the population into two halves, and the other is a ratio without dividing. The ratio would give a proportion to GA and EDA models in the hybrid algorithm, and then the hybrid algorithm could model the system more accurately. For each algorithm, three main errors are calculated which are mean absolute percentage error (MAPE), mean square error (MSE), and root means square error (RMSE). The best result is achieved for hybrid GA-EDA model without dividing the population and the MAPE, RMSE, and MSE values are %0.022, 28944.59 Dollars, and 837789503.79 Dollars, respectively. (C) 2019 by the authors; licensee Growing Science, Canada.

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# Dynamic assignment problem of parking slots

Ratli, Mustapha El Cadi, Abdessamad Ait Jarboui, Bassem Artiba, Abdelhakim

The parking problem has become one of the major issues in urban transportation planning and traffic management research. The present paper deals with the dynamic assignment problem of the parking slots (places). The objectives are to provide a global satisfaction of all customers and maximize parking occupancy. A dynamic assignment problem consists in solving a sequence of assignment problems over time. To cope with all these aspects, we offer in this paper, a new approach based on a learning strategy: an Estimation of Distribution Algorithm (EDA) where a reinforcement learning method is used to support the assignment algorithm. We tested our approach with simulations for over 120 days, using a set of up to 10 parking lots (i.e. with up to 7,000 parking slots) and 13,000 requests distributed with different patterns over a day. The comparative study between an assignment algorithm with and without reinforcement learning algorithm has proven the relevance of our approach: the saving is up to 80%. The results also showed the effects and the benefits of the learning strategy.

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# Study of Via Optimization Problem Based on Estimation of Distribution Algorithm

Chi, Yuhong Yao, Yuxuan Hu, Laihong Wu, Jinying

Optimizing the number of vias is an important approach for improving the performance and the yield of printed circuit boards (PCBs). To optimize the vias of multi-layer PCBs, first, we converted the circuit routing diagram into an undirected weighted topology. Then, the mathematical model of the via optimization problem was established on the basis of the topological weight segmentation method. Finally, it was solved using estimation of distribution algorithm (EDA). Compared with the traditional methods, the proposed method was intuitive and easy to implement with no invalid solution existing in the intermediate process and with high operation efficiency. The simulation experiments demonstrated that the proposed algorithm could effectively solve the via optimization problem, and EDA had faster convergence and better effectiveness than the genetic algorithm (GA).

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# A Tight Runtime Analysis for the cGA on Jump Functions-EDAs Can Cross Fitness Valleys at No Extra Cost

Doerr, Benjamin

We prove that the compact genetic algorithm (cGA) with hypothetical population size mu = Omega(root n log n) boolean AND poly(n) with high probability finds the optimum of any n-dimensional jump function with jump size k &lt; 1/20 In n in O(mu root n) iterations. Since it is known that the cGA with high probability needs at least Omega(mu root n +n log n) iterations to optimize the unimodal ONEMAX function, our result shows that the cGA in contrast to most classic evolutionary algorithms here is able to cross moderate-sized valleys of low fitness at no extra cost.

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# EDA based Deep Neural Network Parameter Optimization

Xu, Qingyang Liu, Anbang

Deep neural network has been applied in kinds of areas due to the excellent performance. The capacity of deep neural network relies on the parameter training algorithm which is always based on the gradient information. However, for deep neural network, it is harder and harder for training due to depth of the neural network and a large number of parameters. Therefore, kinds of techniques are proposed to cope with this problem. However, the training algorithm is almost based on the gradient information with inherent defect. Evolutionary algorithm has the advantage of global optimization capability, independent of gradient information etc. Estimation of distribution algorithm (EDA) is a typical evolutionary algorithm which relies on the probability model of population. Therefore, the EDA is adopted to train the weight and bias of deep neural network in his paper. However, the large scale optimization capability of EDA is limited. Thereby, an improved strategy is proposed to enhance the large scale optimization capability of EDA. In the improved scheme, a random selection strategy is carried out to select partial variables for probability modeling instead of all of the variables, in order to reduce the computing time and the probability of combination explosion. A simulation is carried out to exhibit the validity of the improved algorithm.

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# A New Approach to Generate Solutions Combining Crossover and Estimation of Distribution Operators for EMO Algorithm

Miyamoto, Masahide Watanabe, Shinya

Most of EMO algorithms use crossover operator for generating new solutions. There have been proposed various kinds of crossover in this field and most crossover approaches are good at global optimization but not effective for the problem with strong nonlinearity and dependency.

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# Modified Estimation of Distribution Algorithm for Solving Flow-shop Scheduling Problem with Setup Times

Feng, Mengxuan Kong, Jianshou Liu, Lingyan Liu, Guodong Zhao, Shanshan Zhang, Yue

To solve the flow-shop scheduling problem with sequence dependent setup times, the modified estimation of distribution algorithm was proposed. Considering the setup times dependent on sequence, multi-probability matrixes are employed in the probability model to denote the relative information about jobs in this problem. Meanwhile, the updating mechanism and an automatically adjusting method are improved to adapt to the new probability. A local search is designed to be able to jump out of the local optimum and improve the global optimization ability. Finally, simulation results are compared with other algorithms to demonstrate the effectiveness of the modified EDA.

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# A two-stage assignment strategy for the robust scheduling of dual-resource constrained stochastic job shop scheduling problems

Xiao, Shichang Wu, Zigao Yu, Shaohua

This paper addresses the job shop scheduling problems with stochastic processing times (SJSSP) under machine-worker dual-resource constraints. Considering the difference in worker's proficiency level, a robust scheduling approach is adopted. And then the machine-worker dual-resource constrained robust scheduling model of SJSSP based on the expected scenario of processing times (DR-SJSSP-EPS) is formulated. In view of the requirements of DR-SJSSP-ESP for the rational assignment of the workers, we propose a two-stage assignment strategy (TSAS), which can decrease the random disturbance of the processing times as well as its impact on the scheduling performance. Furthermore, a multi-objective hybrid estimation of distribution algorithm (MO-HEDA) is employed to solve the DR-SJSSP-ESP. At last, the effectiveness of the proposed method to solve the DR-SJSSP-ESP in the job shop manufacturing system is verified according to the simulation results. (C) 2019, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.

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# Finding equitable risk routes for hazmat shipments

Chai, Huo He, Ruichun Ma, Changxi Dai, Cunjie

This paper develops a model to analyse hazmat shipments routing in the context of hazmat transportation between the specified origin-destination (OD) pair. A novel aspect of this model is the consideration of risk equity using the standard deviation, an established computation to assess equity. To solve the model, a two-phase method is developed, in which the multi-objective shortest path algorithm is used to obtain the Pareto-optimal paths set, and get the routes using estimation of distribution algorithm after paths choice. We then present a test problem of hazmat shipment with consideration of risk equity and discuss computational results.

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# A HYBRID ESTIMATION OF DISTRIBUTION ALGORITHM FOR A CONTAINER PRE-MARSHALING PROCESS

Perez-Rodriguez, Ricardo Hernandez-Aguirre, Arturo Nava-Munoz, Sergio Mendez-Gomez-Humaran, Ignacio Manzano-Martinez, Isreal

In a yard storage area, pre-marshaling means relocating the export containers into a proper arrangement in order to increase the efficiency of the load process. The container pre-marshaling process aims to identify the best sequence of movements of container movements on an initial layout of the yard storage area, so that it reaches a desired final layout and satisfies operational constraints, while minimizing the total number of movements required to achieve the best sequence. Contrary to current research, a new evolutionary algorithm is proposed and developed to solve the pre-marshaling problem and simulate the solution. Our approach combines the key advantages of both evolutionary algorithms and the Mallows model. The Mallows distribution is used to model the pre-marshaling scenario, while an evolutionary algorithm is used to guide the overall search process to identify the best performing sequences. The approach makes use of the Mallows model to describe the distribution of the solution space. The proposed algorithm is able to identify the next most probable movement in the yard storage area. General and standard benchmarking and real-world cases served as input and test parameters in order to show the performance of the proposed algorithm.

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# Voronoi Tessellation Optimization A Local/Global Optimization Hybrid for Electromagnetics Design

Jenkins, Ronald P. Werner, Douglas H.

This paper introduces a new hybrid local-global optimizer called the Voronoi Tessellation Optimization (VTO) algorithm which leverages precomputed gradients and a space partitioning technique to improve single objective convergence speed and robustness. VTO has been herein compared with other well-known optimization algorithms used in electromagnetics and optics and has demonstrated commensurate or improved performance on two multimodal test problems.

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# An EDA-GA Hybrid Algorithm for Multi-Objective Task Scheduling in Cloud Computing

Pang, Shanchen Li, Wenhao He, Hua Shan, Zhiguang Wang, Xun

As one of the hot issues in cloud computing, task scheduling is an important way to meet user needs and achieve multiple goals.With the increasing number of cloud users and growing demand for cloud computing, how to reduce the task completion time and improve the system load balancing ability have attracted increasing interest from academia and industry in recent years. To meet the two aforementioned goals, this paper develops an EDA-GA hybrid scheduling algorithm based on EDA(estimation of distribution algorithm) and GA (genetic algorithm). First, the probability model and sampling method of EDA are used to generate a certain scale of feasible solutions. Second, the crossover and mutation operations of GA are used to expand the search range of solutions. Finally, the optimal scheduling strategy for assigning tasks to virtual machines is realized. This algorithm has advantages of fast convergence speed and strong search ability. The algorithm proposed in this paper is compared with EDA and GA via the CloudSim simulation experiment platform. The experimental results show that the EDA-GA hybrid algorithm can effectively reduce the task completion time and improve the load balancing ability.

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# A Decentralized Continuous Estimation of Distribution Algorithm for Networked Systems

Bian, Aizhe Chen, Xi

This paper proposes a decentralized continuous estimation of distribution algorithm to solve optimization problems in large scale networked systems which consist of many subsystems. The decentralized continuous estimation of distribution algorithm makes each subsystem cooperate with its neighbors to find good global solutions. Numerical examples illustrate the effectiveness of the algorithm.

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# Estimation of Distribution Algorithm Based on Levy Flight for Solving the Set-Union Knapsack Problem

Liu, Xue-Jing He, Yi-Chao

This article investigates how to use the estimation of distribution algorithm based on Levy flight to solve the set-union knapsack problem (SUKP). First, the mathematical model of the SUKP is introduced. Then, a quadratic greedy repair and optimization algorithm (Q-GROA), which deals with infeasible solutions, is proposed. Thereby, a new approach, the estimation of distribution algorithm based on Levy flight (LFEDA) combined with the Q-GROA is also proposed to solve the SUKP. A number of experiments are performed on the SUKP datasets to evaluate the performance of our proposed model. The results verify that the proposed method is significantly better than other algorithms with respect to the solution's performance.

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# A Novel Imperialist Competitive Algorithm With Multi-Elite Individuals Guidance for Multi-Object Unrelated Parallel Machine Scheduling Problem

Wang, Mei Pan, Guohua

In this study unrelated parallel machine scheduling problem (UPMSP) with preventive maintenance (PM) and sequence dependent setup times (SDST) is investigated. A novel imperialist competitive algorithm (NICA) with multi-elite individuals guidance is proposed to minimize makespan and total tardiness simultaneously. Initialization is done by two heuristics, each of which is built based on one objective. Multielite individuals guidance strategy is added in assimilation that colonies can move toward other imperialists, diversified strategies such as local search and estimation of distribution algorithm (EDA) are adopted based on solution quality in revolution and EDA is also used in imperialist competition. Empire aggression is added by local search of imperialist for plundering a randomly chosen colony. A number of experiments are conducted on the impact of new strategies and the comparisons among NICA and other algorithms. Computational results demonstrate the effectiveness and advantages of NICA in solving UPSMP with PM and SDST.

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# Using EDA-Based Local Search to Improve the Performance of NSGA-II for Multiobjective Semantic Web Service Composition

Wang, Chen Ma, Hui Chen, Gang

Service-oriented computing is a computing paradigm that creates reusable modules over the Internet, often known as Web services. Web service composition aims to accomplish more complex functions by loosely coupling web services. Researchers have been proposing evolutionary computation (EC) techniques for efficiently building up composite services with optimized non-functional quality (i.e., QoS). Some of these techniques employ multi-objective EC algorithms to handle conflict qualities in QoS for fully automated service composition. One recent state-of-art work hybridizes NSGA-II and MOEA/D, which allows the multi-objective service composition problem to be decomposed into many scalar optimization subproblems, where a simple form of local search can be easily applied. However, their local search is considered to be less effective and efficient because it is randomly applied to a predefined large number of subproblems without focusing on the most suitable candidate solutions. In this paper, we propose a memetic NSGA-II with probabilistic model-based local search based on Estimation of Distribution Algorithm (EDA). In particular, a clustering technique is employed to select suitable Pareto solutions for local search. Each selected solution and its belonged cluster members are used to learn a distribution model that samples new solutions for local improvements. Besides that, a more challenging service composition problem that optimizes both functional and non-functional quality is considered. Experiments have shown that our method can effectively and efficiently produce better Pareto optimal solutions compared to other state-of-art methods in the literature.

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# A Histogram Estimation of Distribution Algorithm for Reversible Lanes Optimization Problems

You, Rui Chen, Wei-Neng Gong, Yue-Jiao Lin, Ying Zhang, Jun

The Reversible lanes optimization problem (RLOP) is a complex optimization problem in traffic management. The objective of this problem is to find an optimal direction assignment of lanes in an urban traffic network, so that the traffic capacity of urban streets could get the utmost promotion. To solve this problem efficiently, we particularly devise a histogram-based estimation of distribution algorithm (HEDA) in this paper. Specifically, during the estimation of the distribution, this algorithm considers different individuals differently based on their contributions. Besides, HEDA also combines both the current and historical population distribution information to generate offspring. Experiments conducted on ten different traffic network instances substantiate that HEDA achieves better performance than the compared method on most instances, especially on large-scale network instances.

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# Random Walk Mutation-based DE with EDA for Nonlinear Equations Systems

Liao, Zuowen Gong, Wenyin Cai, Zhihua Wang, Ling Wang, Yong

Finding multiple roots of nonlinear equations systems (NESs) in a single run is an important yet difficult task. It requires to keep a balance between explorative and exploitative traits. In this paper, we present a random walk mutation-based differential evolution (DE) with estimation of distribution algorithm (EDA) to address this problem. The major characteristics are: i) the random walk mutation is capable of preserving the population diversity, which guides individuals to move toward different promising regions; ii) probability selection is employed to provide suitable parent individuals for evolution; iii) EDA is used to accelerate the convergence and obtains the roots. To evaluate the performance of our approach, 30 NESs with diverse features are selected as test suite. Experimental results indicate that the proposed approach is able to yield better performance compared with other state-of-the-art methods.

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# Solving Dynamic Multi-objective Optimization Problems Using Incremental Support Vector Machine

Hu, Weizhen Jiang, Min Gao, Xing Tan, Kay Chen Cheung, Yiu-ming

The main feature of the Dynamic Multi-objective Optimization Problems (DMOPs) is that optimization objective functions will change with times or environments. One of the promising approaches for solving the DMOPs is reusing the obtained Pareto optimal set (POS) to train prediction models via machine learning approaches. In this paper, we train an Incremental Support Vector Machine (ISVM) classifier with the past POS, and then the solutions of the DMOP we want to solve at the next moment are filtered through the trained ISVM classifier. A high-quality initial population will be generated by the ISVM classifier, and a variety of different types of population-based dynamic multi-objective optimization algorithms can benefit from the population. To verify this idea, we incorporate the proposed approach into three evolutionary algorithms, the multi-objective particle swarm optimization(MOPSO), Nondominated Sorting Genetic Algorithm II (NSGA-II), and the Regularity Model-based multi-objective estimation of distribution algorithm(RE-MEDA). We employ experimentS to test these algorithms, and experimental results show the effectiveness.

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# Search Space Reduction Model with Trigonometric Function for Linear Equality Constraint-handling: The Case of Portfolio Replication Problem

Orito, Yukiko Hanada, Yoshiko Li, Junzhi

In the constrained optimization problem, it is difficult that the evolutionary algorithm finds the optimal solution on the whole solution space. The algorithm needs a constraint-handling technique for obtaining the solutions only in the feasible region. In this paper, for the portfolio replication problem which is the linear equality constrained optimization problem, we propose the search space reduction model with larger dimensionality using trigonometric functions as a new constraint-handling technique. The proposed model is employed in an estimation of distribution algorithm and it is applied to the portfolio replication problem. In the numerical experiments, we show the usefulness of the proposed model as compared with a standard constraint-handling technique.

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# A Deadline-Aware Estimation of Distribution Algorithm for Resource Scheduling in Fog Computing Systems

Wu, Chu-ge Wang, Ling

The Internet of Things (JoT) develops rapidly and has produced a large amount of data these years. A range of responsive IoT applications arise and are needed to be processed in a timely manner. Compared with traditional cloud computing system, fog computing is one of the promising solutions of processing the huge amount of local data and decreasing the end-to-end latency. Hard and soft deadlines are assigned to the tasks of applications to model the users' needs. In this work, the resource allocation and task scheduling problem under fog system is considered to minimize total tardiness of the tasks and meet the hard deadlines. A deadline-aware estimation of distributed algorithm (dEDA) with a repair procedure and local search is adopted to determine the task processing order and computing node allocation. The comparative results show that the solution produced by our proposed algorithm performs better than the algorithm without repair procedure or knowledge driven local search. In addition, the performance of our algorithm exceeds significantly the heuristic method on both total tardiness and successful rate metrics. Compared with the existing fog computing resource management algorithm, our algorithm performs much better under most situations.

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# Configuration Design of Mechanical Assemblies using an Estimation of Distribution Algorithm and Constraint Programming

Cheong, Hyunmin Ebrahimi, Mehran Butscher, Adrian Iorio, Francesco

A configuration design problem in mechanical engineering involves finding an optimal assembly of components and joints that realizes some desired performance criteria. Such a problem is a discrete, constrained, and black-box optimization problem. A novel method is developed to solve the problem by applying Bivariate Marginal Distribution Algorithm (BMDA) and constraint programming (CP). BMDA is a type of Estimation of Distribution Algorithm (EDA) that exploits the dependency knowledge learned between design variables without requiring too many fitness evaluations, which tend to be expensive for the current application. BMDA is extended with adaptive chi-square testing to identify dependencies and Gibbs sampling to generate new solutions. Also, repair operations based on CP are used to deal with infeasible solutions found during search. The method is applied to a vehicle suspension design problem and is found to be more effective in converging to good solutions than a genetic algorithm and other EDAs. These contributions are significant steps towards solving the difficult problem of configuration design in mechanical engineering with evolutionary computation.

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# Migrating Birds Optimization for Lot-streaming flow shop scheduling problem

Han, Yuyan Li, Junqing Liu, Yiping Zheng, Zhixin Pan, Yuxia Sang, Hongyan Liu, Lili

This paper presents a novel migrating birds optimization (NMBO) algorithm for solving the lot-streaming flowshop scheduling problem with minimizing makespan. The proposed NMBO algorithm utilizes discrete job permutations to represent solutions, and applies multiple neighborhoods based on insert and swap operators to improve the leading solution. Two new crossover operators, i.e., similar job order with artificial chromosome crossover, and similar block order crossover are employed to obtain solutions for the rest migrating birds. An initialization scheme based on the problem-specific heuristics is presented to generate an initial population with a certain level of quality and diversity. A local search based on the insert neighborhood is embedded to improve the algorithm's local exploitation ability. NMBO is compared with the existing discrete invasive weed optimization, estimation of distribution algorithm and modified MBO algorithms based on the well-known lot-streaming flow shop benchmark. The computational results and comparison demonstrate the superiority of the proposed NMBO algorithm for the lot-streaming flow shop scheduling problems with makespan criterion.

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# An Efficient Probabilistic Approach Based on Area Grey Incidence Decision Making for Optimal Distributed Generation Planning

Huang, Dawei Li, Hongwei Cai, Guowei Huang, Nantian Yu, Na Huang, Zheng

The increase in the scale of distribution networks significantly reduces the efficiency of intelligent planning for distributed generation (DG). To improve the efficiency of intelligent DG planning and avoid the impact of uncertainty concerning renewable energy on it, this paper proposes a sensitivity index for the bus-embedded multi-objective estimation of distribution algorithm (MEDA) based on the semi-invariant probabilistic power flow approach to achieve an optimal solution. The sensitivity indices of the buses are comprehensively enabled to obtain a new index and determine their sensitivity sequences based on the area grey incidence decision-making method. Subsequently, according to the uncertainty of wind turbine generators and photovoltaics, a probability model is established, and the semi-invariant method is used to solve for the probabilistic power flow according to a correlation model. Finally, the sensitivity of the proposed bus-embedded MEDA to enhancing the efficiency of the solution is examined. The optimal DG allocation scheme is obtained with the goal of achieving the lowest total cost in the planning year. Finally, the feasibility and effectiveness of the proposed model and method are verified using simulations of the IEEE 33-bus, IEEE 69-bus, and IEEE 118-bus test systems.

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# A Multi-model Estimation of Distribution Algorithm

Hao, Li

Estimation of distribution algorithm(EDA) is an effective evolutionary algorithm which is working based on the probabilistic model. On the analysis of EDA, we proposed a novel EDA. In this algorithm, multiple probabilistic models are taken to describe the complex problem, the candidate solutions are obtained through sampling the models, each model learned by direct comparison with its own best solution, and the random exchange of evolution targets between models is used to realize information sharing. By setting the upper and lower limit of probability, premature convergence can be avoided. After analyzing this algorithm, we apply it to the knapsack problem, and comparing with common genetic algorithm(CGA) and PBIL, the experimental results illustrate that the proposed algorithm has better performance.

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# An energy-saving wireless sensor network based model for monitoring of ammonia concentration

Chen, Chong Liu, Xingqiao Zhu, Chengyun Huo, Caihong

The ammonia concentration in the piggery plays a key role in the growth of fattening pigs. An intelligent environmental monitoring system is proposed based on a wireless sensor network. Specifically, a model has been developed to predict environmental parameters in the server. To optimise its prediction accuracy, this model was designed based on least squares support vector regression (LSSVR) with chaotic mutation to improve the estimation of distribution algorithm (CMEDA) for searching of the optimised parameters, which are gamma and sigma. Three optimisation methods were involved and compared with it. The experimental results indicated that it exhibits advantages in the prediction accuracy over the other three algorithms. Furthermore, the prediction accuracy of the server was 95%, resulting in reduction of internet of things (IoT) card flow and battery power of LoRa module per day by 50%. The proposed monitoring system is an effective strategy for piggery environmental control.

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# A Gaussian Estimation of Distribution Algorithm With Random Walk Strategies and Its Application in Optimal Missile Guidance Handover for Multi-UCAV in Over-the-Horizon Air Combat

Wang, Xiaofei Zhao, Hui Han, Tong Wei, Zhenglei Liang, Yajun Li, Yingtong

To overcome the premature convergence caused by the ill-distribution of solutions in the basic Gaussian estimation of distribution algorithm (GEDA), this paper explores a novel GEDA variant with random walk strategies, namely RW-GEDA. In RW-GEDA, the weighted maximum likelihood estimation method is used to estimate the Gaussian distribution. The new candidates are sampled using a shifted mean to enhance exploration performance. When the algorithm stagnates, two random walk strategies, namely, Gaussian random walk and Levy walk, are activated to enrich the population diversity. Moreover, RW-GEDA is executed in an Eigen coordinate framework to promote the evolution towards the dominant region. The performance of RW-GEDA is evaluated by using the CEC 2014 test suite and compared with other top algorithms from different communities as well as promising GEDA extensions. The statistical results demonstrate the competitive performance of our proposed RW-GEDA in terms of efficiency and accuracy. In addition, RW-GEDA is applied to solve the optimal missile guidance handover problem. To fill the gap in solving this problem, a novel missile guidance advantage model is established, and the optimal missile guidance handover is determined by optimizing the control variables of unmanned combat aerial vehicles. The validity and practicability of the problem model as well as the accuracy and efficiency of RW-GEDA are demonstrated by the experimental results.

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# DPM-IEDA: Dual probabilistic Model Assisted Interactive Estimation of Distribution Algorithm for Personalized Search

Chen, Yang Sun, Xiaoyan Gong, Dunwei Yao, Xiangjuan

An interactive evolutionary algorithm (IEA) is powerful for solving personalized search when the user's preference can be well caught, expressed, and applied in the process of searching. Hybrid recommendation by articulating the content-based and collaborative filtering techniques is popular and effective for the personalized recommendation, but has not been developed to improve the performance of IEA for fulfilling the personalized search. Accordingly, we here propose an enhanced interactive estimation of distribution algorithm by designing dual-probabilistic models based on the hybrid recommendation for personalized search. The concept of hybrid personalized search is first defined from the viewpoint of using not only the historical search information but also the social or group preference. A dual-probabilistic model by sufficiently combining the content-based and collaborative filtering is presented and used to design the effective interactive estimation of distribution algorithm (IEDA). The probabilistic model is directly combined with the initialization of IEDA for illuminating the sparsity of the traditional IEA in encoding. The effectiveness of the proposed algorithm in fast and efficient searching with a lower computational cost is experimentally illustrated by two typical personalized searches on movies and TV series described with documents.

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# An Individual and Model-Based Offspring Generation Strategy for Evolutionary Multiobjective Optimization

Du, Guanjun Tong, Guoxiang Xiong, Naixue

According to the Karush-Kuhn-Tucker condition, the Pareto set (PS) of a continuous m-objective optimization problem is a continuous (m - 1)-D piecewise manifold. Based on this regularity property, the ratio of the sum of the first (m - 1) largest eigenvalue of the population's covariance matrix to the sum of the whole eigenvalue can be employed to illustrate the degree of convergence of the population. This paper proposes a new algorithm, named DE/RM-MEDA, which hybridizes differential evolution (DE) and estimation of distribution algorithm (EDA) for multiobjective optimization problems (MOPs) with the complicated PS. In the proposed algorithm, EDA extracts the population distribution information to sample new trial solutions by establishing a probability model, while DE uses the individual information to create others new individuals through the mutation and crossover operators. At each generation, the number of new solutions generated by the two operators is adjusted by the above-defined ratio. The proposed algorithm is validated on nine tec09 problems. The sensitivity and the scalability have also been experimentally investigated in this paper. The comparison results between DE/RM-MEDA and the other two state-of-the-art evolutionary algorithms, namely NSGA-II-DE and RM-MEDA, show that the proposed algorithm is highly competitive algorithms for solving MOPs with complicated PSs in terms of convergence and diversity metrics.

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# ESTHER: Joint Camera Self-Calibration and Automatic Radial Distortion Correction From Tracking of Walking Humans

Tang, Zheng Lin, Yen-Shuo Lee, Kuan-Hui Hwang, Jenq-Neng Chuang, Jen-Hui

Camera calibration and radial distortion correction are the crucial prerequisites for many applications in image big data and computer vision. Many existing works rely on the Manhattan world assumption to estimate the camera parameters automatically; however, they may perform poorly when there was lack of man-made structure in the scene. As walking humans are the common objects in video surveillance, they have also been used for camera self-calibration, but the main challenges include the noise reduction for the estimation of vanishing points, the relaxation of assumptions on unknown camera parameters, and the radial distortion correction. In this paper, we present a novel framework for camera self-calibration and automatic radial distortion correction. Our approach starts with the reliable human body segmentation that is facilitated by robust object tracking. Mean shift clustering and Laplace linear regression are, respectively, introduced in the estimation of the vertical vanishing point and the horizon line. The estimation of distribution algorithm, an evolutionary optimization scheme, is then utilized to optimize the camera parameters and the distortion coefficients, in which all the unknowns in camera projection can be fine-tuned simultaneously. Experiments on the three public benchmarks and our own captured dataset demonstrate the robustness of the proposed method. The superiority of this algorithm is also verified by the capability of reliably converting 2D object tracking into 3D space.

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# A copula-based estimation of distribution algorithm for calibration of microscopic traffic models

Fard, Mehdi Rafati Mohaymany, Afshin Shariat

The importance of calibration of microscopic traffic models as the main core of traffic simulation software results from the need for more realistic traffic behaviors. The latent essence of several parameters in such models as well as the uncertainties resulting from the noise in the data, make the process of calibration much more complex. Usually, the calibration process is formulated as an optimization problem. Selecting the appropriate solution algorithm due to nonlinear and non convex nature of the problem is crucial. The importance of the issue is more significant when the matter of calibrating the medium or large-scale simulation model is considered. This is mainly due to the expensive cost that running the simulation models impose. Therefore, applying the current algorithms in which finding the appropriate solutions requires a large number of simulation runs is not deemed suitable. In this paper, an estimation of distribution algorithm based on copula theory has been suggested. In contrast with traditional solution algorithms, in the proposed algorithm complex interaction between parameters of a model has been considered by constructing and sampling from a copula-based probabilistic model. Copulas are functions that describe the dependence structure of a set of random variables and connect multivariate distribution functions to one-dimensional marginal distribution functions. The results indicate that applying an explicit probabilistic model based on copula helps the estimation of distribution algorithm to explore the search space more effectively and efficiently as well as provides the possibility of extracting the knowledge with regard to the structure of the calibration problem through analyzing the probabilistic models that are constructed during the evolution process. Furthermore, this new algorithm has been compared with the genetic algorithm and kernel-based cross-entropy method on synthetic and real trajectory data. The results confirm that the proposed algorithm is more efficient in terms of convergence rate, resource usage and more robust in terms of the probability of finding the global optimal solution.

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# Improved Renyi Entropy Benchmark for Performance Assessment of Common Cascade Control System

Zhang, Qian Wang, Ya-Gang Lee, Feifei Chen, Qiu Sun, Zhen

To deal with the inconsistency of the minimum variance (MV) benchmark in evaluating non-Gaussian disturbance systems, this paper proposed a new benchmark, which combined entropy with output mean value. For a cascade control system, the new benchmark was constructed by analyzing the weakness of the MV benchmark and the pure Renyi entropy benchmark. In order to estimate the more accurate performance of the unknown system, an improved estimation of distribution algorithm based on entropy criterion is given. It can identify the disturbance distribution and calculate the new index evaluation value. Finally, different disturbance distributions were used to verify the consistency of the new index. The experimental results show that the proposed index and algorithms are consistent and effective in evaluating the performance of the unknown systems with non-Gaussian disturbance.

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# MCEDA: A novel many-objective optimization approach based on model and clustering

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To solve many-objective optimization problems (MaOPs) by evolutionary algorithms (EAs), the maintenance of convergence and diversity is essential and difficult. Improved multi-objective optimization evolutionary algorithms (MOEAs), usually based on the genetic algorithm (GA), have been applied to MaOPs, which use the crossover and mutation operators of GAs to generate new solutions. In this paper, a new approach, based on decomposition and the MOEA/D framework, is proposed: model and clustering based estimation of distribution algorithm (MCEDA). MOEA/D means the multi-objective evolutionary algorithm based on decomposition. The proposed MCEDA is a new estimation of distribution algorithm (EDA) framework, which is intended to extend the application of estimation of distribution algorithm to MaOPs. MCEDA was implemented by two similar algorithm, MCEDA/B (based on bits model) and MCEDA/RM (based on regular model) to deal with MaOPs. In MCEDA, the problem is decomposed into several subproblems. For each subproblem, clustering algorithm is applied to divide the population into several subgroups. On each subgroup, an estimation model is created to generate the new population. In this work, two kinds of models are adopted, the new proposed bits model and the regular model used in RM-MEDA (a regularity model based multi-objective estimation of distribution algorithm). The nondominated selection operator is applied to improve convergence. The proposed algorithms have been tested on the benchmark test suite for evolutionary algorithms (DTLZ). The comparison with several stateof-the-art algorithms indicates that the proposed MCEDA is a competitive and promising approach. (C) 2018 Elsevier B.V. All rights reserved.

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