# A Posteriori Pareto Front Diversification Using a Copula-Based Estimation of Distribution Algorithm

Cheriet, Abdelhakim Cherif, Foudil

We propose CEDA, a Copula-based Estimation of Distribution Algorithm, to increase the size, achieve high diversity and convergence of optimal solutions for a multiobjective optimization problem. The algorithm exploits the statistical properties of Copulas to produce new solutions from the existing ones through the estimation of their distribution. CEDA starts by taking initial solutions provided by any MOEA (Multi Objective Evolutionary Algorithm), construct Copulas to estimate their distribution, and uses the constructed Copulas to generate new solutions. This design saves CEDA the need of running an MOEA every time alternative solutions are requested by a Decision Maker when the found solutions are not satisfactory. CEDA was tested on a set of benchmark problems traditionally used by the community, namely UF1, UF2, ..., UF10 and CF1, CF2, ..., CF10. CEDA used along with SPEA2 and NSGA2 as two examples of MOEA thus resulting in two variants CEDA-SPEA2 and CEDA-NSGA2 and compare them with SPEA2 and NSGA2. The results of The experiments show that, with both variants of CEDA, new solutions can be generated in a significantly smaller without compromising quality compared to those found SPEA2 and NSGA2.

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# An Estimation of Distribution Algorithm With Cheap and Expensive Local Search Methods

Zhou, Aimin Sun, Jianyong Zhang, Qingfu

In an estimation of distribution algorithm (EDA), global population distribution is modeled by a probabilistic model, from which new trial solutions are sampled, whereas individual location information is not directly and fully exploited. In this paper, we suggest to combine an EDA with cheap and expensive local search (LS) methods for making use of both global statistical information and individual location information. In our approach, part of a new solution is sampled from a modified univariate histogram probabilistic model and the rest is generated by refining a parent solution through a cheap LS method that does not need any function evaluation. When the population has converged, an expensive LS method is applied to improve a promising solution found so far. Controlled experiments have been carried out to investigate the effects of the algorithm components and the control parameters, the scalability on the number of variables, and the running time. The proposed algorithm has been compared with two state-of-the-art algorithms on two test suites of 27 test instances. Experimental results have shown that, for simple test instances, our algorithm can produce better or similar solutions but with faster convergence speed than the compared methods and for some complicated test instances it can find better solutions.

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# A Boltzmann-Based Estimation of Distribution Algorithm for a General Resource Scheduling Model

Liang, Xinle Chen, Huaping Lozano, Jose A.

Most researchers employed common functional models when managing scheduling problems with controllable processing times. However, in many complicated manufacturing systems with a high diversity of jobs, these functional resource models fail to reflect their specific characteristics. To fulfill these requirements, we apply a more general model, the discrete model. Traditional functional models can be viewed as special cases of such model. In this paper, the discrete model is implemented on a problem of minimizing the weighted resource allocation subject to a common deadline on a single machine. By reducing the problem to a partition problem, we demonstrate that it is NP-complete, which addresses the difficult issue of the guarantee of both the solution quality and time cost. In order to tackle the problem, we develop an estimation of distribution algorithm based on an approximation of the Boltzmann distribution. The approximation strategy represents a tradeoff between complexity and solution accuracy. The results of the experiments conducted on benchmarks show that, compared with other alternative approaches, the proposed algorithm has competitive behavior, obtaining 74 best solutions out of 90 instances.

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# A hybrid estimation of distribution algorithm for simulation-based scheduling in a stochastic permutation flowshop

Wang, K. Choi, S. H. Lu, H.

The permutation flowshop scheduling problem (PFSP) is NP-complete and tends to be more complicated when considering stochastic uncertainties in the real-world manufacturing environments. In this paper, a two-stage simulation-based hybrid estimation of distribution algorithm (TSSB-HEDA) is presented to schedule the permutation flowshop under stochastic processing times. To deal with processing time uncertainty, TSSB-HEDA evaluates candidate solutions using a novel two-stage simulation model (TSSM). This model first adopts the regression-based meta-modelling technique to determine a number of promising candidate solutions with less computation cost, and then uses a more accurate but time-consuming simulator to evaluate the performance of these selected ones. In addition, to avoid getting trapped into premature convergence, TSSB-HEDA employs both the probabilistic model of EDA and genetic operators of genetic algorithm (GA) to generate the offspring individuals. Enlightened by the weight training process of neural networks, a self-adaptive learning mechanism (SALM) is employed to dynamically adjust the ratio of offspring individuals generated by the probabilistic model. Computational experiments on Taillard's benchmarks show that TSSB-HEDA is competitive in terms of both solution quality and computational performance. (C) 2015 Elsevier Ltd. All rights reserved.

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# An estimation of distribution algorithm and new computational results for the stochastic resource-constrained project scheduling problem

Fang, Chen Kolisch, Rainer Wang, Ling Mu, Chundi

In this paper we propose an estimation of distribution algorithm (EDA) to solve the stochastic resource-constrained project scheduling problem. The algorithm employs a novel probability model as well as a permutation-based local search. In a comprehensive computational study, we scrutinize the performance of EDA on a set of widely used benchmark instances. Thereby, we analyze the impact of different problem parameters as well as the variance of activity durations. By benchmarking EDA with state-of-the-art algorithms, we can show that its performance compares very favorably to the latter, with a clear dominance in instances with medium to high variance of activity duration.

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# Meta-Heuristic Algorithms in Car Engine Design: A Literature Survey

Tayarani-N., Mohammad-H. Yao, Xin Xu, Hongming

Meta-heuristic algorithms are often inspired by natural phenomena, including the evolution of species in Darwinian natural selection theory, ant behaviors in biology, flock behaviors of some birds, and annealing in metallurgy. Due to their great potential in solving difficult optimization problems, meta-heuristic algorithms have found their way into automobile engine design. There are different optimization problems arising in different areas of car engine management including calibration, control system, fault diagnosis, and modeling. In this paper we review the state-of-the-art applications of different meta-heuristic algorithms in engine management systems. The review covers a wide range of research, including the application of meta-heuristic algorithms in engine calibration, optimizing engine control systems, engine fault diagnosis, and optimizing different parts of engines and modeling. The meta-heuristic algorithms reviewed in this paper include evolutionary algorithms, evolution strategy, evolutionary programming, genetic programming, differential evolution, estimation of distribution algorithm, ant colony optimization, particle swarm optimization, memetic algorithms, and artificial immune system.

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# A hybrid estimation of distribution algorithm for the semiconductor final testing scheduling problem

Wang, Shengyao Wang, Ling Liu, Min Xu, Ye

As the last process of the semiconductor fabrication, the final testing is crucial to guarantee the quality of the integrated circuit products. The semiconductor final testing scheduling problem (SFTSP) is of great significance to the efficiency of the semiconductor companies. To find satisfactory solutions within reasonable computational time, the intelligent manufacturing scheduling based on the meta-heuristic methods has become a common approach. In this paper, a hybrid estimation of distribution algorithm (HEDA) is proposed to solve the SFTSP. First, novel encoding and decoding methods are proposed to map from the solution space to the schedule space effectively. Second, a probability model that describes the distribution of the solution space is built to generate the new individuals of the population. Third, a mechanism is used to update the parameters of the probability model with the superior solutions at every generation. Furthermore, to enhance the exploitation ability of the algorithm, a local search procedure is hybridized to find neighbor solutions of the promising individuals obtained by sampling the probability model. In addition, the influence of parameters is investigated based on Taguchi method of design-of-experiment, and a set of suitable parameters is suggested. Finally, numerical simulation based on some benchmark instances is carried out. The comparisons between the HEDA and some existing algorithms demonstrate the effectiveness of the proposed HEDA in solving the SFTSP.

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# Composite Particle Swarm Optimizer With Historical Memory for Function Optimization

Li, Jie Zhang, Junqi Jiang, ChangJun Zhou, MengChu

Particle swarm optimization (PSO) algorithm is a population-based stochastic optimization technique. It is characterized by the collaborative search in which each particle is attracted toward the global best position (gbest) in the swarm and its own best position (pbest). However, all of particles' historical promising pbests in PSO are lost except their current pbests. In order to solve this problem, this paper proposes a novel composite PSO algorithm, called historical memorybased PSO (HMPSO), which uses an estimation of distribution algorithm to estimate and preserve the distribution information of particles' historical promising pbests. Each particle has three candidate positions, which are generated from the historical memory, particles' current pbests, and the swarm's gbest. Then the best candidate position is adopted. Experiments on 28 CEC2013 benchmark functions demonstrate the superiority of HMPSO over other algorithms.

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# A hybrid evolutionary algorithm with guided mutation for minimum weight dominating set

Chaurasia, Sachchida Nand Singh, Alok

This paper presents a hybrid evolutionary algorithm with guided mutation (EA/G) to solve the minimum weight dominating set problem (MWDS) which is -hard in nature not only for general graphs, but also for unit disk graphs (UDG). MWDS finds practical applications in diverse domains such as clustering in wireless networks, intrusion detection in adhoc networks, multi-document summarization in information retrieval, query selection in web databases etc. EA/G is a recently proposed evolutionary algorithm that tries to overcome the shortcomings of genetic algorithms (GAs) and estimation of distribution algorithms (EDAs) both, and that can be considered as a cross between the two. The solution obtained through EA/G algorithm is further improved through an improvement operator. We have compared the performance of our hybrid evolutionary approach with the state-of-the-art approaches on general graphs as well as on UDG. Computational results show the superiority of our approach in terms of solution quality as well as execution time.

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# An improved EDA for solving Steiner tree problem

Liu, Lei Wang, Hua Kong, Guohong

Steiner tree problem and its derivations are widely employed to optimize the design of transportation, communication networks, biological engineering and the QoS multicast routing problem. It is one of well-defined open issues which have attracted many research efforts. Different from the existing works, this paper develops a new method of solving Steiner tree problem by using the improved estimation of distribution algorithms (EDA). Further, the performance of developed method is validated by applying on multicast routing optimization. The developed method randomly initializes n trees which contain the source node and the destination nodes. And some individuals select the crossover operation randomly to add the population diversity and avoid the algorithm premature convergence. The algorithm constructs a probabilistic model according to the selected elites, which is capable of estimating the probability distribution of the solution. The probabilistic model is updated according to the new population. New trees are generated based on the probabilistic model. This process iterated until designated termination criteria are met. The improved EDA algorithm gradually evolves trees to obtain a better solution. Simulation validations suggest that the developed method leads to better performance. In particular, the complexity in terms of the converging speed improves significantly compared to other algorithms. Copyright (c) 2015 John Wiley &amp; Sons, Ltd.

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# A fast estimation of distribution algorithm for dynamic fuzzy flexible job-shop scheduling problem

Liu, Bojun Fan, Yushun Liu, Yi

Due to the complicated circumstances in workshop, most of the conventional scheduling algorithms fail to meet the requirements of instantaneity, complexity, and dynamicity in job-shop scheduling problems. Compared with the static algorithms, dynamic scheduling algorithms can better fulfill the requirements in real situations. Considering that both flexibility and fuzzy processing time are common in reality, this paper focuses on the dynamic flexible job-shop scheduling problem with fuzzy processing time (DfFJSP). By adopting a series of transforming procedures, the original DfFJSP is simplified as a traditional static fuzzy flexible job-shop problem, which is more suitable to take advantage of the existing algorithms. In this paper, estimation of distribution algorithm (EDA) is brought into address the post-transforming problem. An improved EDA is developed through making use of several elements omitted in original EDA, including the historical-optimal solution and the standardized solution vectors. The improved algorithm is named as fast estimation of distribution algorithm (fEDA) since it performs better in convergence speed and computation precision, compared with the original EDA. To sum up, the ingenious transformation and the effective fEDA algorithm provide an efficient and practical way to tackle the dynamic flexible fuzzy job-shop scheduling problem. (C) 2015 Elsevier Ltd. All rights reserved.

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# A hybrid multi-objective PSO-EDA algorithm for reservoir flood control operation

Luo, Jungang Qi, Yutao Xie, Jiancang Zhang, Xiao

Reservoir flood control operation (RECO) is a complex multi-objective optimization problem (MOP) with interdependent decision variables. Traditionally, RECO is modeled as a single optimization problem by using a certain scalar method. Few works have been done for solving multi-objective RECO (MO-RECO) problems. In this paper, a hybrid multi-objective optimization approach named MO-PSO-EDA which combines the particle swarm optimization (PSO) algorithm and the estimation of distribution algorithm (EDA) is developed for solving the MO-RECO problem. MO-PSO-EDA divides the particle population into several sub-populations and builds probability models for each of them. Based on the probability model, each sub-population reproduces new offspring by using PSO based and EDA methods. In the PSO based method, a novel global best position selection method is designed. With the help of the EDA based reproduction, the algorithm can lean linkage between decision variables and hence have a good capability of solving complex multi-objective optimization problems, such as the MO-RECO problem. Experimental studies on six benchmark problems and two typical multi-objective flood control operation problems of Ankang reservoir have indicated that the proposed MO-PSO-EDA performs as well as or superior to the other three competitive multi-objective optimization algorithms. MO-PSO-EDA is suitable for solving MO-RECO problems. (C) 2015 Elsevier B.V. All rights reserved.

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# Solving the 0-1 Quadratic Knapsack Problem with a competitive Quantum Inspired Evolutionary Algorithm

Patvardhan, C. Bansal, Sulabh Srivastav, A.

Quadratic Knapsack Problem (QKP) extends the canonical simple Knapsack Problem where the value obtained by selecting a subset of objects is a function dependent not only on the value corresponding to individual objects selected but also on their pair-wise selection. QKP is NP Hard in stronger sense i.e. no pseudo-polynomial time algorithm is known to exist which can solve QKP instances. QKP has been studied intensively due to its simple structure yet challenging difficulty and numerous applications. Quantum Inspired Evolutionary Algorithm (QIEA) belongs to the class of Evolutionary Algorithms and exhibits behaviour of an Estimation of Distribution Algorithm (EDA). QIEA provides a generic framework that has to be carefully tailored for a given problem to obtain an effective implementation. Thus, several forms of QIEA exist in the literature. These have been successfully applied on many hard problems. A new QIEA, QIEA-PSA is proposed with improved exploration and exploitation capabilities. Computational experiments on these benchmarks show that QIEA-PSA is improved significantly both in terms of the quality of solutions and speed of convergence on several benchmark QKP instances. The ideas incorporated are general enough and can be utilized with advantage on other similar and not so similar problems. (C) 2015 Elsevier B.V. All rights reserved.

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# Improving Estimation of Distribution Algorithm on Multimodal Problems by Detecting Promising Areas

Yang, Peng Tang, Ke Lu, Xiaofen

In this paper, a novel multiple sub-models maintenance technique, named maintaining and processing submodels (MAPS), is proposed. MAPS aims to enhance the ability of estimation of distribution algorithms (EDAs) on multimodal problems. The advantages of MAPS over the existing multiple sub-models based EDAs stem from the explicit detection of the promising areas, which can save many function evaluations for exploration and thus accelerate the optimization speed. MAPS can be combined with any EDA that adopts a single Gaussian model. The performance of MAPS has been assessed through empirical studies where MAPS is integrated with three different types of EDAs. The experimental results show that MAPS can lead to much faster convergence speed and obtain more stable solutions than the compared algorithms on 12 benchmark problems.

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# Pilot Pattern Optimization for Sparse Channel Estimation in OFDM Systems

Wang, Han Guo, Qing Zhang, Gengxin Li, Guangxia Xiang, Wei

Compressive sensing (CS) based sparse channel estimation requires optimal pilot patterns, whose corresponding sensing matrices should have small mutual coherences, so as to efficiently exploit the inherent channel sparsity. For the purpose of minimizing the mutual coherence of the sensing matrix, we introduce a new estimation of distribution algorithm (EDA) to optimize the pilot pattern so as to improve the channel estimation performance. The proposed scheme guides the optimization process by building and sampling the probability distribution model of the promising pilot indexes, and approaches the optimal pilot pattern iteratively. The algorithm is able to not only preserve the current best pilot indexes, but also introduce diversity by sampling new ones, and hence is unlikely to trap into local minima and more robust than other methods. Simulation results show that our proposed method can generate sensing matrices with smaller mutual coherences than existing methods, and the corresponding optimized pilot pattern performs well in terms of sparse channel estimation.

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# A continuous estimation of distribution algorithm for the online order-batching problem

Perez-Rodriguez, Ricardo Hernandez-Aguirre, Arturo Joens, S.

In manual order-picking systems such as picker-toparts, order pickers walk through a warehouse in order to pick up articles required by customers. Order batching consists of combining these customer orders into picking orders. In online batching, customer orders arrive throughout the scheduling. This paper considers an online order-batching problem in which the turnover time of all customer orders has to be minimized, i.e., the time period between the arrival time of the customer order and its completion time. A continuous estimation of distribution algorithm-based approach is proposed and developed to solve the problem and implement the solution. Using this approach, the warehouse performance can be noticeably improved with a substantial reduction in the average turnover time of a set of customer orders.

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# Unsupervised Dynamic Fuzzy Cognitive Map

Liu, Boyuan Fan, Wenhui Xiao, Tianyuan

Fuzzy Cognitive Map (FCM) is an inference network, which uses cyclic digraphs for knowledge representation and reasoning. Along with the extensive applications of FCMs, there are some limitations that emerge due to the deficiencies associated with FCM itself. In order to eliminate these deficiencies, we propose an unsupervised dynamic fuzzy cognitive map using behaviors and nonlinear relationships. In this model, we introduce dynamic weights and trend-effects to make the model more reasonable. Data credibility is also considered while establishing a machine learning model. Subsequently, we develop an optimized Estimation of Distribution Algorithm (EDA) for weight learning. Experimental results show the practicability of the dynamic FCM model. In comparison to the other existing algorithms, the proposed algorithm has better performance in terms of convergence and stability.

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# Interval-based ranking in noisy evolutionary multi-objective optimization

Karshenas, Hossein Bielza, Concha Larraaga, Pedro

As one of the most competitive approaches to multi-objective optimization, evolutionary algorithms have been shown to obtain very good results for many real-world multi-objective problems. One of the issues that can affect the performance of these algorithms is the uncertainty in the quality of the solutions which is usually represented with the noise in the objective values. Therefore, handling noisy objectives in evolutionary multi-objective optimization algorithms becomes very important and is gaining more attention in recent years. In this paper we present -degree Pareto dominance relation for ordering the solutions in multi-objective optimization when the values of the objective functions are given as intervals. Based on this dominance relation, we propose an adaptation of the non-dominated sorting algorithm for ranking the solutions. This ranking method is then used in a standard multi-objective evolutionary algorithm and a recently proposed novel multi-objective estimation of distribution algorithm based on joint variable-objective probabilistic modeling, and applied to a set of multi-objective problems with different levels of independent noise. The experimental results show that the use of the proposed method for solution ranking allows to approximate Pareto sets which are considerably better than those obtained when using the dominance probability-based ranking method, which is one of the main methods for noise handling in multi-objective optimization.

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# Reduction of carbon emissions and project makespan by a Pareto-based estimation of distribution algorithm

Zheng, Huan-yu Wang, Ling

Due to the increasing concerns about global warming, low-carbon production has been a hot topic around the world. In this paper, carbon emissions reduction and project makespan minimization are considered simultaneously. To formulate the problem, a multi-objective multi-mode resource-constrained project scheduling model with makespan and carbon emissions criteria is given. To solve the problem, a Pareto-based estimation of distribution algorithm (PBEDA) is proposed. Specifically, an activity-mode list is used to encode the individual of the population; a hybrid probability model is built to describe the probability distribution of the solution space; and two Pareto archives are adopted to store the explored non-dominated solutions and the solutions for updating the probability model, respectively. New individuals are generated in the promising search areas by sampling and updating the hybrid probability model. Besides, Taguchi method of design of experiments is adopted to study the effect of parameter setting. Finally, numerical results and the comparisons to other algorithms are provided to show the effectiveness of the PBEDA in terms of quantity and quality of the obtained solutions. The Pareto set derived by the PBEDA can be helpful for project manager to recognize the relationship between carbon emissions and makespan so as to properly trade-off the two criteria according to certain preference. (C) 2014 Elsevier B.V. All rights reserved.

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# Approach to Hybrid Flow-Shop Scheduling Problem Based on Self-Guided Genetic Algorithm

Dai, Wen-Zhan Xia, Kai

The effective self-guided genetic algorithm (SGGA) which we proposed is based on the characteristics of a hybrid flow shop scheduling problem. A univariate probability model based on workpiece permutation is introduced together with a bivariate probability model based on a similar workpiece blocks. An approach to updating a probability model parameters is given based on superior individuals. A novel probability calculation function is proposed taking advantages of statistical learning information provided by univariate and bivariate probabilistic model to calculate the probability of workpieces located in different positions. A method for evaluating the quality of individual candidates generated by GA crossover and mutation operators is suggested for selecting promising and excellent individual candidates as offspring. Simulation results show that the SGGA has excellent performance and robustness.

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# A New Evolutionary Algorithm with Structure Mutation for the Maximum Balanced Biclique Problem

Yuan, Bo Li, Bin Chen, Huanhuan Yao, Xin

The maximum balanced biclique problem (MBBP), an NP-hard combinatorial optimization problem, has been attracting more attention in recent years. Existing node-deletion-based algorithms usually fail to find high-quality solutions due to their easy stagnation in local optima, especially when the scale of the problem grows large. In this paper, a new algorithm for the MBBP, evolutionary algorithm with structure mutation (EA/SM), is proposed. In the EA/SM framework, local search complemented with a repair-assisted restart process is adopted. A new mutation operator, SM, is proposed to enhance the exploration during the local search process. The SM can change the structure of solutions dynamically while keeping their size (fitness) and the feasibility unchanged. It implements a kind of large mutation in the structure space of MBBP to help the algorithm escape from local optima. An MBBP-specific local search operator is designed to improve the quality of solutions efficiently; besides, a new repair-assisted restart process is introduced, in which the Marchiori's heuristic repair is modified to repair every new solution reinitialized by an estimation of distribution algorithm (EDA)-like process. The proposed algorithm is evaluated on a large set of benchmark graphs with various scales and densities. Experimental results show that: 1) EA/SM produces significantly better results than the state-of-the-art heuristic algorithms; 2) it also outperforms a repair-based EDA and a repair-based genetic algorithm on all benchmark graphs; and 3) the advantages of EA/SM are mainly due to the introduction of the new SM operator and the new repair-assisted restart process.

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# Archimedean copula estimation of distribution algorithm based on artificial bee colony algorithm

Xu, Haidong Jiang, Mingyan Xu, Kun

The artificial bee colony (ABC) algorithm is a competitive stochastic population-based optimization algorithm. However, the ABC algorithm does not use the social information and lacks the knowledge of the problem structure, which leads to insufficiency in both convergent speed and searching precision. Archimedean copula estimation of distribution algorithm (ACEDA) is a relatively simple, time-economic and multivariate correlated EDA. This paper proposes a novel hybrid algorithm based on the ABC algorithm and ACEDA called Archimedean copula estimation of distribution based on the artificial bee colony (ACABC) algorithm. The hybrid algorithm utilizes ACEDA to estimate the distribution model and then uses the information to help artificial bees to search more efficiently in the search space. Six benchmark functions are introduced to assess the performance of the ACABC algorithm on numerical function optimization. Experimental results show that the ACABC algorithm converges much faster with greater precision compared with the ABC algorithm, ACEDA and the global best (gbest)-guided ABC (GABC) algorithm in most of the experiments.

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# Design of Passive Analog Electronic Circuits using Hybrid Modified UMDA Algorithm

Slezak, Josef Gotthans, Tomas

Hybrid evolutionary passive analog circuits synthesis method based on modified Univariate Marginal Distribution Algorithm (UMDA) and a local search algorithm is proposed in the paper. The modification of the UMDA algorithm which allows to specify the maximum number of the nodes and the maximum number of the components of the synthesized circuit is proposed. The proposed hybrid approach efficiently reduces the number of the objective function evaluations. The modified UMDA algorithm is used for synthesis of the topology and the local search algorithm is used for determination of the parameters of the components of the designed circuit. As an example the proposed method is applied to a problem of synthesis of the fractional capacitor circuit.

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# Adaptive Memetic Computing for Evolutionary Multiobjective Optimization

Shim, Vui Ann Tan, Kay Chen Tang, Huajin

Inspired by biological evolution, a plethora of algorithms with evolutionary features have been proposed. These algorithms have strengths in certain aspects, thus yielding better optimization performance in a particular problem. However, in a wide range of problems, none of them are superior to one another. Synergetic combination of these algorithms is one of the potential ways to ameliorate their search ability. Based on this idea, this paper proposes an adaptive memetic computing as the synergy of a genetic algorithm, differential evolution, and estimation of distribution algorithm. The ratio of the number of fitter solutions produced by the algorithms in a generation defines their adaptability features in the next generation. Subsequently, a subset of solutions undergoes local search using the evolutionary gradient search algorithm. This memetic technique is then implemented in two prominent frameworks of multiobjective optimization: the domination- and decomposition-based frameworks. The performance of the adaptive memetic algorithms is validated in a wide range of test problems with different characteristics and difficulties.

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# Reconfiguration of satellite orbit for cooperative observation using variable-size multi-objective differential evolution

Chen, Yingguo Mahalec, Vladimir Chen, Yingwu Liu, Xiaolu He, Renjie Sun, Kai

A novel self-adaptive variable-size multi-objective differential evolution algorithm is presented to find the best reconfiguration of existing on-orbit satellites for some particular targets on the ground when an emergent requirement arises in a short period. The main contribution of this study is that three coverage metrics are designed to assess the performance of the reconfiguration. Proposed algorithm utilizes the idea of fixed-length chromosome encoding scheme combined with expression vector and the modified initialization, mutation, crossover and selection operators to search for optimal reconfiguration structure. Multi-subpopulation diversity initialization is adopted first, then the mutation based on estimation of distribution algorithm and adaptive crossover operators are defined to manipulate variable-length chromosomes, and finally a new selection mechanism is employed to generate well-distributed individuals for the next generation. The proposed algorithm is applied to three characteristically different case studies, with the objective to improve the performance with respect to specified targets by minimizing fuel consumption and maneuver time. The results show that the algorithm can effectively find the approximate Pareto solutions under different topological structures. A comparative analysis demonstrates that the proposed algorithm outperforms two other related multi-objective evolutionary optimization algorithms in terms of quality, convergence and diversity metrics. (C) 2014 Elsevier B.V. All rights reserved.

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# An order-based estimation of distribution algorithm for stochastic hybrid flow-shop scheduling problem

Wang, Sheng-yao Wang, Ling Liu, Min Xu, Ye

In view of the stochastic nature of the data in real-world manufacturing systems, it is crucial to develop effective algorithms to solve the scheduling problems with uncertainty. In this paper, an order-based estimation of distribution algorithm (OEDA) is proposed to solve the hybrid flow-shop scheduling problem (HFSP) with stochastic processing times. Considering the effectiveness and robustness of a schedule, it aims to minimise the makespan of the initial scenario as well as the deviation of all results of the stochastic scenarios and the initial one. To be specific, a bi-objective function is used to evaluate the individuals of the population, and a probability model is designed to describe the probability distribution of the solution space. Meanwhile, optimal computing budget allocation (OCBA) technique is employed to provide a reliable identification to the good solutions among the population. A mechanism is also presented to update the probability model with the superior individuals that are identified by the OCBA. The new individuals are generated by sampling the probability model to track the area with promising solutions. In addition, the influence of parameter setting is investigated based on Taguchi method of design-of-experiment (DOE), and a suitable parameter setting is suggested. Extensive numerical testing results and comparisons with the existing algorithm are provided, which demonstrate the effectiveness of the proposed OEDA.

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# A novel multi-objective estimation of distribution algorithm for solving gas lift allocation problem

Miresmaeili, S. Omid H. Pourafshary, Peyman Farahani, Farhang Jalali

Gas lifting is a common practice in the oil industry. Using an appropriate gas lift injection rate can ensure that the desired oil production rate would be achieved. In the case of an oil field, the problem of distributing a certain amount of the available gas among a number of wells is formally known as a gas lift allocation problem. In this paper, a multi-objective optimization algorithm, based on the Gaussian Bayesian Networks and the Gaussian kernels, is proposed in order to determine the best injection points, considering multiple objective functions. Firstly, the problem is solved in a similar approach to the previous literature with similar gas lift data and similar function approximation method, to compare the performance of the proposed algorithm with the older ones. Thereafter, an extended problem is discussed, with minimizing the water production as a new optimization criterion. The developed multi-objective scheme is capable of handling and optimizing a gas-lift problem with several constraints and conflicting objectives such as controlling the gas usage and increasing the oil production, whereas in the conventional single-objective optimizations, any alteration in the constraints demands a new optimization process and often there is no place for considering an additional objective in the gas-lift allocation problem. The results obtained by the proposed optimization algorithm significantly overcame those reported in the previous similar literature. For a single-objective fifty-six well problem, the results exhibited 16.24% improvement in the total oil production. (C) 2015 Elsevier B.V. All rights reserved.

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# Design optimization of a cable-based parallel tracking system by using evolutionary algorithms

Hernandez, Eusebio E. Valdez, S. -I. Ceccarelli, M. Hernandez, A. Botello, S.

In this paper, an optimization design of a 6 DOF parallel measuring system is analyzed. First, a closed form direct kinematics formulation based on Cayley-Menger determinants is considered in the objective function, in order to measure the manipulator singularities, then an estimation of distribution algorithm is proposed to solve the optimization problem. It is shown that the evolutionary algorithm can find close to optimal solutions for minimum pose error estimation. Additionally, these global optimizers significantly reduce the computational burden in comparison with exhaustive search and other global optimization techniques. The sensitivity of the pose error estimation in the prescribed robots' workspace is analyzed and used to guide a designer in choosing the best structural configuration. Numerical examples are discussed to show the feasibility of the proposed optimization methodology.

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# An improved multiobjective estimation of distribution algorithm for environmental economic dispatch of hydrothermal power systems

Li, Yangyang He, Haiyang Wang, Yang Xu, Xia Jiao, Licheng

Environmental economic dispatch of fixed head of hydrothermal power systems is viewed as a mulitobjective optimization problem in this paper. The practical hydrothermal system possesses various constraints which make the problem of finding global optimum difficult. This paper develops an improved multiobjective estimation of distribution algorithm to solving the above problem. A local learning operation is added into the original regularity model-based multiobjective estimation of distribution algorithm (RM-MEDA) in the improved approach so as to improve the local search ability and enhance the convergence efficiency. Furthermore, a repair mechanism is employed to repair the searched infeasible solutions in order to be able to search in the feasible region. In the experiment, the results obtained by the proposed approach have been compared with those from other three MOEAs: NSGA-II, NNIA, and RM-MEDA. Results from some pervious reported methods have also been employed to compare with our method. In addition, the results demonstrate the superiority of this proposed method as a promising MOEA to solve this power system multiobjective optimization problem. (C) 2014 Elsevier B.V. All rights reserved.

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# Research on Gain Scheduling Controller of the Networked Control System with Long Delay

Deng, Jian-Qiu Li, Hong-Bo Hao, Cui Sun, Zeng-Qi

This paper addresses the stabilization and optimization problem of networked control systems (NCSs) with long time delays and parameter scheduling. According to the actual network conditions, the network time delay is divided into the fixed time delay and the random time delay. Then, the stabilization controller and the gain scheduling controller are constructed, where the stabilizing control parameters are obtained with cone complementary linearization (CCL) approach and the optimizing control parameters are solved with estimation of distribution algorithm (EDA). Simulation results demonstrate the effectiveness of the proposed methods.

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# Continuous probabilistic model building genetic network programming using reinforcement learning

Li, Xianneng Hirasawa, Kotaro

Recently, a novel probabilistic model-building evolutionary algorithm (so called estimation of distribution algorithm, or EDA), named probabilistic model building genetic network programming (PMBGNP), has been proposed. PMBGNP uses graph structures for its individual representation, which shows higher expression ability than the classical EDAs. Hence, it extends EDAs to solve a range of problems, suchas data mining and agent control. This paper is dedicated to propose a continuous version of PMBGNP for continuous optimization in agent control problems. Different from the other continuous EDAs, the proposed algorithm evolves the continuous variables by reinforcement learning (RL). We compare the performance with several state-of-the-art algorithms on a real mobile robot control problem. The results show that the proposed algorithm outperforms the others with statistically significant differences. (C) 2014 Elsevier B.V. All rights reserved.

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# A research overview of manifold-learning-based multiobjective evolutionary algorithm

Zhan, Wei Guo, Chao Xiong, Leiping

Manifold learning algorithm can find out the low-dimensional smooth manifold embedded in high-dimensional data. So, in this paper, the manifold learning algorithm is introduced into multiobjective optimisation algorithm for multiobjective optimisation problems (MOPs), and a manifold-learning-based multiobjective evolutionary algorithm (ML-MOEA) is proposed to overcome deficiency of the traditional evolutionary multi-objective optimisation algorithms (EMOAs) and model-based multi-objective optimisation algorithms (MOEAs) for reducing dimension of data and mining manifold in the decision space of MOPs, build accurate model, guide algorithm evolution and accelerate convergence. The steps of ML-MOEA is as follows: 1) randomly initialisation; 2) modelling via manifold learning algorithm; 3) extend and reproduction; 4) elite selection; 5) halt or go to step 2. Based on the framework of ML-MOEA, a ML-MOEA via self-organising maps (ML-MOEA/SOM) and a ML-MOEA via SOM locally linear embedding (ML-MOEA/LLE) is proposed, and comparison experiment of algorithm performance is done.

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# Estimation of distribution algorithm with scatter search for dynamic optimisation problems

Yu, Fahong He, Feng Chen, Meijia Ma, Longhua Lu, Zheming

Aiming at the trouble to track the optima in dynamic environments with estimation of distribution algorithms (EDAs). An estimation of distribution algorithm with scatter search (EDASS) is proposed in this paper. Its basic idea is to employ a scatter search to increase the diversity in a guided fashion and an adaptive leader clustering method to locate multiple local optima. Both the information of current population and the part history information were referred for building probability model. The experimental results show that the EDASS is effective for dynamic optimisation problems.

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# Scale Adaptive Reproduction Operator for Decomposition based Estimation of Distribution Algorithm

Wang, Bo Xu, Hua Yuan, Yuan

Multi-objective evolutionary algorithm based on decomposition (MOEA/D) uses crossover operator which often either breaks the building blocks or mix them ineffectively. Multi-objective estimation of distribution algorithm based on decomposition (MEDA/D) evolves a probability vector for each sub-problem to guide the search instead of using crossover operator. However, since the number of the weight vectors in the neighborhood of each weight vector is relatively small and MEDA/D does not provide a way to maintain diversity, the performance of MEDA/D is limited. To overcome the drawbacks of MEDA/D, we proposed a new reproduction operator. This operator could promote diversity. We introduced it into MOEA/D framework and the new algorithm is called s-MEDA/D. We also prove that the parameter newly introduced has physical significance and the reproduction operator is not susceptible to the scale of the problem. The s-MEDA/D was tested on nine instances of the 0/1 multi-objective knapsack problem. Empirical evaluation suggests that the proposed algorithm is effective and efficient.

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# A modified Alopex-based evolutionary algorithm and its application on parameter estimation

He, Pengfei Li, Shaojun

In order to improve the efficiency of an Alopexbased evolutionary algorithm (AEA), a modified AEA algorithm (CAEA) which combines copula estimation of distribution algorithm (copula EDA) is introduced in this paper. In view of the inefficiency and the lack of adequate evolutionary information for the population in AEA, a set of competitive and elite solutions are acquired to improve the quality and maintain the diversity of the candidate population by using EDA based on copula. The modified algorithm not only takes advantage of heuristic search of AEA, but also inherits the superiority of rapid convergence of copula EDA. Then 22 benchmark functions are employed to test the performance of CAEA algorithm. Compared with AEA, EDA and differential evolution (DE), the optimization results indicate that the performance of CAEA is significantly superior to that of the other three algorithms, no matter in accuracy or in stability. Furthermore, the modified algorithm is applied to estimating the parameters of a fermentation dynamics model. The results of the comparisons with the other two algorithms illustrate that CAEA algorithm is effective in practical engineering application.

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# AUTOMATED SHAPE OPTIMIZATION USING A MULTIGRID METHOD AND ESTIMATION OF DISTRIBUTION ALGORITHMS

Valdez, S. I. Faurrieta, N. Marroquin, J. L. Botello, S.

Topological shape optimization refers to the problem of finding the optimal shape of a mechanical structure by using a process for removing or inserting new holes or parts, it is to say, using a process which produces topological changes. This article introduces a method for automated topological optimization via an Estimation of Distribution Algorithm (EDA) with a suitable representation of the optimization variables. The optimum structure is such with the minimum weight which does not exceed a maximum von Mises stress and displacement. The contributions of this proposal resides in the definition of a candidate solution and the optimization method. The candidate solution representation is independent of the finer discretization used for analyzing candidate structures using the finite element method. Given a domain Omega, which corresponds to the physical space where candidate structures reside, a vector phi = [phi(1), phi(2), ..., phi(m)] is used to define a smooth function (phi) over cap (x, y) on Omega. If (phi) over cap (x, y) is less than 0.5, such region does not have material, otherwise, it has. The smooth function phi(x, y) provides the advantage of having continuous regions with or without material while it depends on few optimization parameters 0, in addition, we can define an arbitrary number of parts or gaps as thinner or larger as needed. The EDA benefits from this representation, sampling random arbitrary structures and using probabilistic learning to determine whether a region must have material. The EDA is a global optimizer which can propose different topologies without the need of a priori knowledge neither initial solutions. In addition it uses a probabilistic model which smoothly evolve through generations. In consequence, at the beginning of the optimization process it arbitrarily proposes topologically different structures, while at the convergence phase it performs similar to a local search algorithm. The EDA uses few parameters which can be set in a straight forward manner. We report several study cases from the specialized literature, showing that our proposal outperforms reported results from up-to-date well performed algorithms.

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# Transmission Expansion Planning Based on Hybrid EDA/DE Algorithm Considering Wind Power Penetration

Liu, Wenxia Li, He Xu, Huiting Zhang, Jianhua Zheng, Dehua

It poses high requirements for the calculation speed and the precision of the solving method when we consider the large-scale transmission expansion planning (TEP) problems. Therefore, combined with the respective characteristics of EDA (Distribution of Estimation Algorithm) and DE (Differential Evolution algorithm), this paper puts forward a new hybrid EDA/DE algorithm for large-scale TEP problems. Meanwhile, it improves the updating mechanism of probabilistic model of EDA based on the characteristics of the TEP problems. Considering the investments of grid company, the new energy incentive politics and network security constraints, this paper proposes a multi-objective static planning model for the TEP considering wind power penetration, which takes the comprehensive cost, the wind curtailment and the risk value into consideration. Finally, a specific example is applied in this paper to verify the applicability and effectiveness of the proposed model and algorithm.

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# Efficient Multiple Lines Outage Detection in SmartGrid

Ahmed, Ashfaq Awais, Muhammad Naeem, Muhammad Iqbal, Muhammad Alpalagan, Alagan

To avoid blackouts in the energy system, the knowledge of the state of the power lines has critical importance. To get the timely conscience, Phasor Measurement Units (PMUs) are used to provide real-time synchronized measurements of voltage and current phasors of the buses. The deployment of PMUs is done to first detect any single or multiple line outage, and further to identify the correct line in outage. But if these approaches are applied to more multiple line outages, the search space grows exponentially. To reduce the computational complexity in case of multiple line outage detection, stochastic optimization methods can be used. These methods give near optimal solution with an acceptable computational complexity. In this paper, the use of phasor angle measurements and optimal deployment of PMUs to identify multiple power line outages is investigated. An adaptive version of estimation of distribution algorithm (EDA) is proposed to detect and identify the lines in outage. In this adaptive EDA thresholding technique is introduced in order to get better solutions. It is shown that the proposed algorithm is achieving a better success rate than the other evolutionary techniques.

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# Double-Objective Optimal Control for Non-Gaussian Systems: An Example Study on Analytical vs Numerical Solutions

Ren, Mifeng Zhang, Jianhua Wang, Hong Huang, Min

Minimum entropy control has been proven to be an effective method in control of non Gaussian stochastic systems. In this case, the entropy is proposed as a generalization of the variance measure to characterize the randomness of the process. Minimum entropy corresponds to small uncertainty (or derivation), but it cannot guarantee the tracking error approaching to zero. Therefore, mean square error also should be added in the criterion. In this paper, by using a simple example, the method of generating a representative approximation of the Pareto optimal control set is investigated in both analytical and numerical ways. And simulation results show the feasibility of the proposed double objective optimal control method. (C) 2015, IFAC (International Federation or Automatic Control) Hosting by Elsevier Ltd. All rights reserved.

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# A New Grammatical Evolution Based on Probabilistic Context-free Grammar

Kim, Hyun-Tae Ahn, Chang Wook

This paper presents a new grammatical evolution (GE) that generates automatic program under favor of probabilistic context-free grammar. A population of individuals is evolved under genotypic integer strings and a mapping process is utilized to translate from genotype (i.e., integer string) to phenotype (i.e., complete program). To efficiently handle this process, unlike the standard GE that employs a simple modulo function, the probability concept is introduced to context-free grammar, thereby choosing production rules according to assigned probabilities. Moreover, any crossover and mutation are not employed for generating new individuals. Instead, along the lines of estimation of distribution algorithms that perform search using a probabilistic model of superior individuals, a new population is created/evolved from probabilistic relationship between production rules. A comparative study on the standard GE and the proposed GE is conducted; the performance achieved by the both methods is comparable. Also, the experimental results firmly demonstrate the effectiveness of the proposed approach.

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# Applying an Extension of Estimation of Distribution Algorithm (EDA) for Mobile Robots to Learn Motion Patterns from Demonstration

Tan, Huan

This paper proposes a probabilistic evolutionary computing algorithm for robots to learn motion patterns. This algorithm is inspired from Estimation of Distribution Algorithms (EDA). The distribution of chromosomes (not the genes), which have higher fitness values in the configuration space, is estimated in a configuration space. A modified Probabilistic Rapidly-growing Random Tree (PRRT)-Connect algorithm is used for searching the configuration space to generate chromosomes which are represented as paths from the starting point to the goal point. Mutation is defined as searching with certain probability outside of the current distribution area (obstacle-free area). This algorithm is applied for robotic learning of motion trajectories through imitation. Simulation and practical experimental results are given in this paper to verify the effectiveness of this algorithm. The major contribution of this paper is proposing an extension of current EDAs, which could be applied for rapid robotic imitation learning.

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# Non-integrated Algorithm based on EDA and Tabu Search for Test Task Scheduling Problem

Lu, Hui Zhang, Mengmeng

The optimization of test task scheduling problem (TTSP) is an important issue in automatic test system (ATS). TTSP is a complex combination optimization problem and includes two sub-problems. They are test task sequencing and test scheme combination. According to the characteristic of TTSP, a non-integrated algorithm based on estimation of distribution algorithm and Tabu Search (EDA-TS) is proposed in this paper. EDA focuses on solving test task sequencing in global searching, and TS emphasizes on solving test scheme combination in local searching. In addition, we give a mathematical model for TTSP. We prove that TTSP is an NP-hard by using traveling salesman problem (TSP) based on the mathematical model. The statistical results of single objective TTSP suggest that our approach has a stronger searching ability and good convergence compared with other three popular algorithms. The experiments of the multi-objectives TTSP also illustrate that EDA-TS has a strong searching ability and can maintain a diversity of solutions.

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# Transmission Expansion Planning Based on Hybrid EDA/DE Algorithm Considering Wind Power Penetration

Wen, Xiankui Xu, Huiting Xiao, Yong Chen, Jianguo Lin, Chenghui

It poses high requirements for the calculation speed and the precision of the solving method when we consider the large-scale transmission expansion planning (TEP) problems. Therefore, combined with the respective characteristics of EDA (Distribution of Estimation Algorithm) and DE (Differential Evolution algorithm), this paper puts forward a new hybrid EDA/DE algorithm for large-scale TEP problems. Meanwhile, it improves the updating mechanism of probabilistic model of EDA based on the characteristics of the TEP problems. Considering the investments of power system, the new energy incentive politics and network security constraints, this paper proposes a multi-objective static planning model for the TEP considering wind power penetration, which takes the comprehensive cost, the wind curtailment and the risk value into consideration. Finally, a specific example is applied in this paper to verify the applicability and effectiveness of the proposed model and algorithm.

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# Improved Particle Optimization Algorithm Solving Hadoop Task Scheduling Problem

Xu, Jun Tang, Yong

Cloud computing to provide service for the user group is huge, so the number of cloud computer's tasks is enormous, the system handle large tasks all the time so that task scheduling is the key and difficult points in the cloud. This article make research on how to make full use of cloud resources for task efficiently scheduling. This paper proposes an Improved Particle Swarm-Estimation of Distribution optimization Algorithm (IPS-EDA) based on task allocation strategy. The task scheduling strategy is optimization strategy based on improved particle swarm algorithm, which introduce estimation of distribution algorithm (EDA) based probabilistic model and random sampling theory, the proposed algorithm does not fall into local optimum. The simulation results show that the performance of IPS-EDA has been greatly improved provides better load balancing and resource utilization.

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# MBMEDA: An Application of Estimation of Distribution Algorithms to the Problem of Finding Biological Motifs

Jordan, Carlos I. Jordan, Carlos. J.

In this work we examine the problem of finding biological motifs in DNA databases. The problem was solved by applying MBMEDA, which is a evolutionary method based on the Estimation of Distribution Algorithm (EDA). Though it assumes statistical independence between the main variables of the problem, results were quite satisfactory when compared with those obtained by other methods; in some cases even better. Its performance was measured by using two metrics: precision and recall, both taken from the field of information retrieval. The comparison involved searching a motif on two types of DNA datasets: synthetic and real. On a set a five real databases the average values of precision and recall were 0.866 and 0.798, respectively.

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# Solving Multi-Objective Semiconductor Assembly and Test Manufacturing Scheduling Problem Based on Estimation of Distribution Algorithm

Zhong, Xincheng Liu, Chang Zhu, Jun Han, Dongbin Yuan, Zhiling

In order to solve the problem that, from the current practical perspective of semiconductor assembly and test manufacturing (ATM), the traditional multi-objective optimization algorithm is difficult to realize the practical decision of the enterprise, this paper proposes a new multi-objective estimation of distribution algorithm (EDA) to solve the ATM scheduling problem. According to the demand of the ATM enterprise based on sub-module using two modeling ideas, objectives were divided into two categories: constrained objective and optimized objective, and the different objective had the different searching process. Finally, it used the new algorithm to solve the multi-objective ATM scheduling problem. The result shows that the novel algorithm has the good feasibility and it also has an obvious advantage, the better practicability and maneuverability, compared with the traditional multi-objective optimization methods.

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# Equality Constraint-handling Technique with Various Mapping Points: The Case of Portfolio Replication Problem

Orito, Yukiko Hanada, Yoshiko

For solving an equality constrained optimization problem, it is difficult to find an optimal solution by using any evolutionary algorithms. We propose a new technique that handles an equality constraint in this paper. The technique transforms variables of solution on equality constrained search space to them on unconstrained search space through trigonometrical functions. Thus, this paper presents the contribution that an evolutionary algorithm effectively finds good feasible solutions without evolutionary stagnation because an unconstrained space consists only of feasible solutions. However, our technique searches mapping points only on the part of constrained space because it cannot transform the constrained space to fully unconstrained space. Therefore, we expand such a space consisting of various mapping points by exchanging trigonometrical functions on EDA (Estimation of Distribution Algorithm). In numerical experiments, for portfolio replication problems, we demonstrate the effectiveness of our technique.

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# Designing the Boltzmann Estimation of Multivariate Normal Distribution: issues, goals and solutions

Segovia-Dominguez, Ignacio Hernandez-Aguirre, Arturo Ivvan Valdez, S.

This paper introduces a new Estimation of Distribution Algorithm (EDA) based on the multivariate Boltzmann distribution. In this work, the design variables and the energy function of the Boltzmann distribution are continuous. Note that since the population has finite size, it can only approximate a continuous Boltzmann distribution with some error. In order to tackle this issue, the parameter estimators for the mean vector and covariance matrix of a Multivariate Normal Density that approximate the Boltzmann density, are derived by minimizing the Kullback-Leibler divergence. The algorithm introduced here uses one energy function for the mean estimator and another for the covariance matrix estimator. The first function places the probability mass around the most promising regions by assigning larger weights to individuals with higher fitness. However, the second function orients the covariance matrix along improving directions by assigning larger weights to individuals with lower fitness. Our proposal combines the conveniences of linear weights with a simple annealing schedule to regulate the exploration and exploitation of the search process. The resulting algorithm is named the Boltzmann Estimation of Multivariate Normal Algorithm (BEMNA). By applying the developed formulae the BEMNA is capable of adapting the structure of a density model to the promisory search directions. BEMNA is tested with a benchmark of 16 functions and contrasted with the AMaLGaM algorithm, a state of the art EDA. Statistical tests of the experimental data show the competitiveness of the proposed algorithm.

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# Clustering Molecular Dynamics Trajectories with a Univariate Estimation of Distribution Algorithm

Barros, Rodrigo C. Quevedo, Christian V. De Paris, Renata Basgalupp, Marcio P.

Molecular Dynamics simulations of protein receptors are an emergent tool in rational drug discovery. Nevertheless, employing Molecular Dynamics trajectories in virtual screening of large repositories is a very costly procedure, which ultimately may become unfeasible. Data clustering have been applied in this context with the goal of reducing the overall computational cost in order to make this task feasible. In this paper, we develop a novel estimation of distribution algorithm called Clus-EDA for clustering entire trajectories using structural features from the substrate-binding cavity of the protein receptor. This novel approach is capable of reducing the original trajectory to about 4% of its original size whilst keeping all relevant information for the analysis of receptor-ligand binding. The resulting partition generated by the estimation of distribution algorithm is further validated by analyzing the interactions between 20 ligands and a Fully-Flexible Receptor model containing a 20 ns Molecular Dynamics simulation trajectory. Results show that Clus-EDA is capable of outperforming traditional clustering algorithms such as k-means and hierarchical clustering by providing the smallest variance of the free energy of binding within the conformations in each cluster.

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# Optimization by Pairwise Linkage Detection, Incremental Linkage Set, and Restricted / Back Mixing: DSMGA-II

Hsu, Shih-Huan Yu, Tian-Li

This paper proposes a new evolutionary algorithm, called DSMGA-II, to efficiently solve optimization problems via exploiting problem substructures. The proposed algorithm adopts pairwise linkage detection and stores the information in the form of dependency structure matrix (DSM). A new linkage model, called the incremental linkage set, is then constructed by using the DSM. Inspired by the idea of optimal mixing, the restricted mixing and the back mixing are proposed. The former aims at efficient exploration under certain constrains. The latter aims at exploitation by refining the DSM so as to reduce unnecessary evaluations. Experimental results show that DSMGA-II outperforms LT-GOMEA and hBOA in terms of number of function evaluations on the concatenated/folded/cyclic trap problems, NK-landscape problems with various degrees of overlapping, 2D Ising spin-glass problems, and MAX-SAT. The investigation of performance comparison with P3 is also included.

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# An Estimation of Distribution Algorithm based on the Natural Gradient and the Boltzmann Distribution

Segovia-Dominguez, Ignacio Hernandez-Aguirre, Arturo

This paper introduces an Estimation of Distribution Algorithm (EDA), in which the parameters of the search distribution are updated by the natural gradient technique. The parameter updating is guided via the Kullback-Leibler divergence between the multivariate Normal and the Boltzmann densities. This approach makes sense because it is well-known that the Boltzmann function yields a reliable model to simulate particles near to optimum locations.

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# Simplified Runtime Analysis of Estimation of Distribution Algorithms

Duc-Cuong Dang Lehre, Per Kristian

Estimation of distribution algorithms (EDA) are stochastic search methods that look for optimal solutions by learning and sampling from probabilistic models. Despite their popularity, there are only few rigorous theoretical analyses of their performance. Even for the simplest EDAs, such as the Univariate Marginal Distribution Algorithm (UMDA) which assumes independence between decision variables, there are only a handful of results about its runtime, and results for simple functions such as ONEMAX are still missing.

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# Novel Absorber Based on Pixelated Frequency Selective Surface Using Estimation of Distribution Algorithm

Zhao, Mengyun Yu, Xiaowei Wang, Qiao Kong, Peng He, Yun Miao, Ling Jiang, Jianjun

A novel design method for absorber is presented, based on pixelated FSS with common effect of metallic pixels and lumped resistors. Considering the relative position of resistors and pixelated patches, the estimation of distribution algorithm is firstly employed to optimize the absorbing performance. Optimization process demonstrates its availability and high-efficiency. An absorption band (3.08-6.00 GHZ) below dB formed with two strong absorption peaks is achieved, compared with the poor absorption performance in pixelated FSS without resistors. The simulated surface current distributions suggest that the loaded resistors are the main source for energy loss of incident electromagnetic wave, and provide an intuitive explanation to the correlation of optimized unit cell geometry and corresponding absorption peaks. The designed absorber is fabricated and the measured reflectivity curve fits well with the simulated results, which indicates that the availability of novel design method.

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# Solution of a flexible jobshop scheduling problem using an Estimation of Distribution Algorithm

Perez, R. Joens, S. Hernandez, A.

The flexible jobshop scheduling problem permits the operation of each job to be processed by more than one machine. The configuration mentioned generally seeks to minimize the completion time of all jobs known in the literature as 'makespan'. We propose an Estimation of Distribution Algorithm for Sequencing, AEDS for simplicity and functionality. The AEDS attempts to find a relationship or interaction between the input variables, jobs, operations and shifts to optimize the output variable of real manufacturing processes, the makespan. In this sense the AEDS algorithm is used to guide the search and to solve the problem. In the algorithm, three graphical models were used to find better solutions. To set off-duty hours for operators before starting their activities in each shift as an input parameter and its development through the AEDS algorithm is a novelty of this research on the current research work. The comparison between AEDS and a genetic algorithm shows the effectiveness of AEDS solving the problem statement. Using the AEDS proposed, the performance Of real manufacturing processes can be improved significantly when different machines are assigned to different schedules.

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# A bi-population EDA for solving the no-idle permutation flow-shop scheduling problem with the total tardiness criterion

Shen, Jing-nan Wang, Ling Wang, Sheng-yao

In this paper, an effective bi-population estimation of distribution algorithm (BEDA) is presented to solve the no-idle permutation flow-shop scheduling problem (NIPFSP) with the total tardiness criterion. To enhance the search efficiency and maintain the diversity of the whole population, two sub-populations are used in the BEDA. The two sub-populations are generated by sampling the probability models that are updated differently for the global exploration and the local exploitation, respectively. Meanwhile, the two sub-populations collaborate with each other to share search information for adjusting the models. To well adjust the models for generating promising solutions, the global probability model is updated during the evolution with the superior population and the local probability model is updated with the best solution that has been explored. To further enhance exploitation in the promising region, the insertion operator is used iteratively as the local search procedure. To investigate the influence of parameter setting, numerical study based on the Taguchi method of design-of-experiment is carried out. The effectiveness of the hi-population strategy and local search procedure is shown by numerical comparisons, and the comparisons with the recently published algorithms by using the benchmarking instances also demonstrate the effectiveness of the proposed BEDA. (C) 2014 Elsevier B.V. All rights reserved.

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