# A novel modified binary differential evolution algorithm and its applications

Wang, Ling Fu, Xiping Mao, Yunfei Menhas, Muhammad Ilyas Fei, Minrui

Differential Evolution (DE) is a simple yet efficient global optimization algorithm. However, the standard DE and most of its variants operate in the continuous space, which cannot solve the binary-coded optimization problems directly. To tackle this problem, this paper proposes a novel modified binary differential evolution algorithm (NMBDE) inspired by the concept of Estimation of Distribution Algorithm and DE. A novel probability estimation operator is developed for NMBDE, which can efficiently maintain diversity of population and achieve a better tradeoff between the exploration and exploitation capabilities by cooperating with the selection operator. Furthermore, the parameter study of NMBDE is run and the analysis is performed to improve the global search ability and scalability of algorithm. The effectiveness and efficiency of NMBDE was verified in applications to the numerical optimization and multidimensional knapsack problems. The experimental results demonstrate that NMBDE has the better global search ability and outperforms the discrete binary DE, the modified binary DE, the discrete binary Particle Swarm Optimization and the binary Ant System in terms of accuracy and convergence speed. (c) 2012 Elsevier B.V. All rights reserved.

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# Detection of Financial Statement Fraud Using Evolutionary Algorithms

Alden, Matthew E. Bryan, Daniel M. Lessley, Brenton J. Tripathy, Arindam

In this paper, we use a Genetic Algorithm (GA) and MARLEDA-a modern Estimation of Distribution Algorithm (EDA)-to evolve and train several fuzzy rule-based classifiers (FRBCs) to detect patterns of financial statement fraud. We find that both GA and MARLEDA demonstrate a better ability to classify unseen corporate data observations than those of a traditional logistic regression model, and provide validity for detecting financial statement fraud with Evolutionary Algorithms (EAs) and FRBCs. Using ten-fold cross-validation, the GA and MARLEDA yield average training classification accuracy rates of 75.47 percent and 74.26 percent, respectively, and average validation accuracy rates of 63.75 percent and 64.46 percent, respectively.

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# Improved Mutual Information Maximizing Input Clustering Algorithm for Permutation Flow Shop Scheduling Problem

Gao, Huimin Wang, Xiaoping

Improved Mutual Information Maximizing Input Clustering algorithm is a kind of discrete estimation of distribution algorithm, which is convenient to solve permutation flow shop scheduling problem. In this paper, the encoding mode and probability model are improved, new individual strategy is proposed, greedy algorithm is introduced at the initial phase of the probability matrix, and crossover operator, mutation operator, insert operator and swap operator are adopted during the process of evolution, dynamic adjusted method is employed to determine the population size. These improvements gurantee the population diversity even in small population. Experiment results show that the improved Mutual Information Maximizing Input Clustering algorithm is effective and stable.

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# Improved Hybrid Differential Evolution-Estimation of Distribution Algorithm with Feasibility Rules for NLP/MINLP Engineering Optimization Problems

Bai Liang Wang Junyan Jiang Yongheng Huang Dexian

In this paper, an improved hybrid differential evolution-estimation of distribution algorithm (IHDE-EDA) is proposed for nonlinear programming (NLP) and mixed integer nonlinear programming (MINLP) models in engineering optimization fields. In order to improve the global searching ability and convergence speed, IHDE-EDA takes full advantage of differential information and global statistical information extracted respectively from differential evolution algorithm and annealing mechanism-embedded estimation of distribution algorithm. Moreover, the feasibility rules are used to handle constraints, which do not require additional parameters and can guide the population to the feasible region quickly. The effectiveness of hybridization mechanism of IHDE-EDA is first discussed, and then simulation and comparison based on three benchmark problems demonstrate the efficiency, accuracy and robustness of IHDE-EDA. Finally, optimization on an industrial-size scheduling of two-pipeline crude oil blending problem shows the practical applicability of IHDE-EDA.

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# Experimental Comparison of Six Population-Based Algorithms for Continuous Black Box Optimization

Posik, Petr Kubalik, Jiri

Six population-based methods for real-valued black box optimization are thoroughly compared in this article. One of them, Nelder-Mead simplex search, is rather old, but still a popular technique of direct search. The remaining five (POEMS, G3PCX, Cauchy EDA, BIPOP-CMA-ES, and CMA-ES) are more recent and came from the evolutionary computation community. The recently proposed "comparing continuous optimizers" (COCO) methodology was adopted as the basis for the comparison. The results show that BIPOP-CMA-ES reaches the highest success rates and is often also quite fast. The results of the remaining algorithms are mixed, but Cauchy EDA and POEMS are usually slow.

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# A regularity model-based multiobjective estimation of distribution algorithm with reducing redundant cluster operator

Wang, Yong Xiang, Jian Cai, Zixing

A regularity model-based multiobjective estimation of distribution algorithm (RM-MEDA) has been proposed for solving continuous multiobjective optimization problems with variable linkages. RM-MEDA is a kind of estimation of distribution algorithms and, therefore, modeling plays a critical role. In RM-MEDA, the population is split into several clusters to build the model. Moreover, the fixed number of clusters is recommended in RM-MEDA when solving different kinds of problems. However, based on our experiments, we find that the number of clusters is problem-dependent and has a significant effect on the performance of RM-MEDA. Motivated by the above observation, in this paper we improve the clustering process and propose a reducing redundant cluster operator (RRCO) to build more precise model during the evolution. By combining RRCO with RM-MEDA, we present an improved version of RM-MEDA, named IRM-MEDA. In this paper, we also construct four additional continuous multiobjective optimization test instances. The experimental results have shown that IRM-MEDA outperforms RM-MEDA in terms of efficiency and effectiveness. In particular, IRM-MEDA performs on average 31.67% faster than RM-MEDA. (c) 2012 Elsevier B.V. All rights reserved.

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# Global search algorithms using a combinatorial unranking-based problem representation for the critical node detection problem

Ventresca, Mario

In this paper the problem of critical node detection (CNDP) is approached using population-based incremental learning (an estimation of distribution algorithm) and simulated annealing optimization algorithms using a combinatorial unranking-based problem representation. This representation is space-efficient and alleviates the need for any repair mechanisms. CNDP is a very recently proposed problem that aims to identify a vertex set V' subset of V of k &gt; 0 nodes from a given graph G = (V,E) such that G(V\V') has minimum pairwise connectivity. Numerous practical applications for this problem exist, including pandemic disease mitigation, computer security and anti-terrorism. In order to test the proposed heuristics 16 benchmark random graph structures are additionally proposed that utilize Erdos-Renyi, Watts-Strogatz, Forest Fire and Barabasi-Albert models. Each of these models presents different network characteristics, yielding variations in problem difficulty. The relative merits of the two proposed approaches are compared and it is found that the population-based incremental learning approach, using a windowed perturbation operator is able to outperform the proposed simulated annealing method. (c) 2012 Elsevier Ltd. All rights reserved.

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# A review on probabilistic graphical models in evolutionary computation

Larranaga, Pedro Karshenas, Hossein Bielza, Concha Santana, Roberto

Thanks to their inherent properties, probabilistic graphical models are one of the prime candidates for machine learning and decision making tasks especially in uncertain domains. Their capabilities, like representation, inference and learning, if used effectively, can greatly help to build intelligent systems that are able to act accordingly in different problem domains. Evolutionary algorithms is one such discipline that has employed probabilistic graphical models to improve the search for optimal solutions in complex problems. This paper shows how probabilistic graphical models have been used in evolutionary algorithms to improve their performance in solving complex problems. Specifically, we give a survey of probabilistic model building-based evolutionary algorithms, called estimation of distribution algorithms, and compare different methods for probabilistic modeling in these algorithms.

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# Parameter estimation of industrial PET reactor using multi-objective kernel density estimation of distribution algorithm

Luo, Na Qian, Feng

With a multitude of reaction pathways, poly (ethylene-terephthalate) (PET) polymerization of industrial practice is complex, and the quality of PET is normally described in terms of several experimentally measured indices. In this paper, parameters estimation of industrial PET reactors is presented as a multi-objective problem to make the mathematic model consistent with the actual industrial process. Considering the interrelation among parameters and the failure of general optimization algorithms, a new multi-objective estimation of distribution algorithm is proposed. Kernel density estimation is used to make the new population more suitable for real-life problems instead of Gaussian model during the evolution of the algorithm. Strategies including selection of kernel width, sampling method and Pareto domination selection are used to explore and exploit the search space more efficiently. With industrial operating data identified in steady state and eliminated from gross error, kinetic parameters are estimated by minimizing carboxyl end group concentration and degree of polymerization simultaneously using the proposed algorithm. The simulation results show that the model with estimated parameters has better predictive performance compared with the experimental parameters. Copyright (c) 2011 Curtin University of Technology and John Wiley &amp; Sons, Ltd.

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# AN ENTROPY APPROACH TO EVALUATION RELAXATION FOR BAYESIAN OPTIMIZATION ALGORITHM

Hai Thi Thanh Nguyen Hoang Ngoc Luong Ahn, Chang Wook

Bayesian Optimization Algorithm (BOA), a multivariate estimation of distribution algorithm, needs incorporating with efficiency enhancement techniques to be capable of solving difficult large-scale problems in a reliable and scalable manner. In this paper, we present a novel evaluation relaxation method which is based on the conditional entropy measurement. The concept of conditional entropy is rigorously analyzed and then is used to investigate the stability of the population. Especially, we utilize the evaluation relaxation strategy (ERS) proposed herein to determine whether a candidate solution should be evaluated by actual functions or be estimated by surrogate models. BOA coupled with our entropy-based ERS, termed en-BOA, shows its superiority in significantly reducing the total number of expensive fitness evaluations until reliable convergence. Experimental results prove that the entropy-based ERS enhances the efficiency of BOA while not negatively affecting the scalability of the original algorithm. In addition, the effects of our efficiency enhancement technique on population sizing requirements are also discussed.

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# A Hybrid Estimation of Distribution Algorithm with Decomposition for Solving the Multiobjective Multiple Traveling Salesman Problem

Shim, V. A. Tan, K. C. Cheong, C. Y.

Evolutionary multiobjective optimization with decomposition, in which the algorithm is not required to differentiate between the dominated and nondominated solutions, is one of the promising approaches in dealing with multiple conflicting objectives. In this paper, the estimation of distribution algorithm (EDA) is integrated into the decomposition framework. The search behavior of the algorithm is further enhanced by hybridizing local search metaheuristic approaches with the decomposition EDA. Three local search techniques, including hill climbing, simulated annealing, and evolutionary gradient search, are considered. A novel multiobjective formulation of the multiple traveling salesman problem is proposed. The hybrid algorithms are used to solve the formulated problem with different number of objective functions, salesmen, and problem sizes. The effectiveness and efficiency of the algorithms are tested and benchmarked against several state-of-the-art multiobjective evolutionary paradigms.

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# Effective search for Pittsburgh learning classifier systems via estimation of distribution algorithms

Yang, Jiadong Xu, Hua Jia, Peifa

Pittsburgh-style learning classifier systems (LCSs), in which an entire candidate solution is represented as a set of variable number of rules, combine supervised learning with genetic algorithms (GAS) to evolve rule-based classification models. It has been shown that standard crossover operators in GAs do not guarantee an effective evolutionary search in many sophisticated problems that contain strong interactions between features. In this paper, we propose a Pittsburgh-style learning classifier system based on the Bayesian optimization algorithm with the aim of improving the effectiveness and efficiency of the rule structure exploration. In the proposed method, classifiers are generated and recombined at two levels. At the lower level, single rules contained in classifiers are produced by sampling Bayesian networks which characterize the global statistical information extracted from the current promising rules in the search space. At the higher level, classifiers are recombined by rule-wise uniform crossover operators to keep the semantics of rules in each classifier. Experimental studies on both artificial and real world binary classification problems show that the proposed method converges faster while achieving solutions with the same or even higher accuracy compared with the original Pittsburgh-style LCSs. (C) 2012 Elsevier Inc. All rights reserved.

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# Computational intelligence-based energy management for a large-scale PHEV/PEV enabled municipal parking deck

Su, Wencong Chow, Mo-Yuen

There is a growing need to address the potential problems caused by the emergence of Plug-in Hybrid Electric Vehicles (PHEVs) and Plug-in Electric Vehicles (PEVs) within the next 10 years. In the near future, a large number of PHEVs/PEVs in our society will add a large-scale energy load to our power grids, as well as add substantial energy resources that can be utilized. The large penetration of these vehicles into the marketplace poses a potential threat to the existing power grid. The existing parking infrastructure is not ready for the large penetration of plug-in vehicles and the high demand of electricity. Nowadays, the advanced computational intelligence methods can be applied to solve large-scale optimization problems in a Smart Grid environment. In this paper, authors propose and implement a suite of computational intelligence-based algorithms (e.g., Estimation of Distribution Algorithm, Particle Swarm Optimization) for optimally managing a large number of PHEVs/PEVs charging at a municipal parking station. Authors characterize the performance of the proposed methods using a Matlab simulation, and compare it with other optimization techniques. (C) 2011 Elsevier Ltd. All rights reserved.

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# A Probabilistic Fragment-Based Protein Structure Prediction Algorithm

Simoncini, David Berenger, Francois Shrestha, Rojan Zhang, Kam Y. J.

Conformational sampling is one of the bottlenecks in fragment-based protein structure prediction approaches. They generally start with a coarse-grained optimization where mainchain atoms and centroids of side chains are considered, followed by a fine-grained optimization with an all-atom representation of proteins. It is during this coarse-grained phase that fragment-based methods sample intensely the conformational space. If the native-like region is sampled more, the accuracy of the final all-atom predictions may be improved accordingly. In this work we present EdaFold, a new method for fragment-based protein structure prediction based on an Estimation of Distribution Algorithm. Fragment-based approaches build protein models by assembling short fragments from known protein structures. Whereas the probability mass functions over the fragment libraries are uniform in the usual case, we propose an algorithm that learns from previously generated decoys and steers the search toward native-like regions. A comparison with Rosetta AbInitio protocol shows that EdaFold is able to generate models with lower energies and to enhance the percentage of near-native coarse-grained decoys on a benchmark of 20 proteins. The best coarse-grained models produced by both methods were refined into all-atom models and used in molecular replacement. All atom decoys produced out of EdaFold's decoy set reach high enough accuracy to solve the crystallographic phase problem by molecular replacement for some test proteins. EdaFold showed a higher success rate in molecular replacement when compared to Rosetta. Our study suggests that improving low resolution coarse-grained decoys allows computational methods to avoid subsequent sampling issues during all-atom refinement and to produce better all-atom models. EdaFold can be downloaded from http://www.riken.jp/zhangiru/software/.

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# A restarted estimation of distribution algorithm for solving sudoku puzzles

Maire, Sylvain Prissette, Cyril

In this paper, we describe a stochastic algorithm to solve sudoku puzzles. Our method consists in computing probabilities for each symbol of each cell updated at each step of the algorithm using estimation of distributions algorithms (EDA). This update is done using the empirical estimators of these probabilities for a fraction of the best puzzles according to a cost function. We develop also some partial restart techniques in the RESEDA algorithm to obtain a convergence for the most difficult puzzles. Our algorithm is tested numerically on puzzles with various levels of difficulty starting from very easy ones to very hard ones including the famous puzzle AI Escargot. The CPU times vary from few hundreds of a second for the easy ones to about one minute for the most difficult one.

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# A compact genetic algorithm for the network coding based resource minimization problem

Xing, Huanlai Qu, Rong

In network coding based data transmission, intermediate nodes in the network are allowed to perform mathematical operations to recombine (code) data packets received from different incoming links. Such coding operations incur additional computational overhead and consume public resources such as buffering and computational resource within the network. Therefore, the amount of coding operations is expected to be minimized so that more public resources are left for other network applications.

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# A hybrid EDA with ACS for solving permutation flow shop scheduling

Tzeng, Yeu-Ruey Chen, Chun-Lung Chen, Chuen-Lung

This paper proposes a hybrid estimation of distribution algorithm (EDA) with ant colony system (ACS) for the minimization of makespan in permutation flow shop scheduling problems. The core idea of EDA is that in each iteration, a probability model is estimated based on selected members in the iteration along with a sampling method applied to generate members from the probability model for the next iteration. The proposed algorithm, in each iteration, applies a new filter strategy and a local search method to update the local best solution and, based on the local best solution, generates pheromone trails (a probability model) using a new pheromone-generating rule and applies a solution construction method of ACS to generate members for the next iteration. In addition, a new jump strategy is developed to help the search escape if the search becomes trapped at a local optimum. Computational experiments on Taillard's benchmark data sets demonstrate that the proposed algorithm generated high-quality solutions by comparing with the existing population-based search algorithms, such as genetic algorithms, ant colony optimization, and particle swarm optimization.

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# Selection of fuel channels for Thermal Power Measurement in 700 MWe Indian PHWR by evolutionary algorithm

Mishra, Surendra Modak, R. S. Ganesan, S.

This paper presents studies on the design of Thermal Power Monitoring System (TPMS) for the forthcoming 700 MWe Indian Pressurized Heavy Water Reactor (PHWR). This reactor contains total 392 horizontal fuel channels. Each channel contains clustered natural Uranium fuel along with associated heavy water coolant placed inside a pressure tube. The coolant in different fuel channels is physically and thermally isolated from each other inside the core. It is necessary to select 44 fuel channels (out of 392) for keeping instrumentation to measure flow and temperature of coolant. The reactor is logically divided into 7 radial zones each containing certain number of fuel channels. The selection of instrumented channels is to be made such that power measured by them in terms of per unit basis represents the true zone-wise and global powers fairly accurately. This should be possible for a large number of reactor configurations that can occur because of the movement of reactivity devices in the core. Such a study is useful to make the TPMS more accurate means to measure the reactor bulk power and zone powers. The choice of 44 channels is an optimization problem in which the error in zonal and global power prediction is to be minimized. There are several constraints on the selection of instrumented channels. Therefore, a constrained combinatorial optimization problem has to be solved. An evolutionary technique based on Estimation of Distribution Algorithm (EDA) is used for this purpose. A suitable pattern of 44 instrumented channels is obtained for which errors in zonal and global powers are less than 0.5% and 2.0% respectively. The equilibrium state of the core with 357 possible device configurations is considered for the optimization. (C) 2012 Elsevier B.V. All rights reserved.

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# A bi-population based estimation of distribution algorithm for the flexible job-shop scheduling problem

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

In this paper, an effective bi-population based estimation of distribution algorithm (BEDA) is proposed to solve the flexible job-shop scheduling problem (FJSP) with the criterion to minimize the maximum completion time (makespan). The BEDA stresses the balance between global exploration and local exploitation. In the framework of estimation of distribution algorithm, two sub-populations are used to adjust the machine assignment and operation sequence respectively with a splitting criterion and a combination criterion. At the initialization stage, multiple strategies are utilized in a combination way to generate the initial solutions. At the global exploration phase, a probability model is built with the superior population to generate the new individuals and a mechanism is proposed to update the probability model. At the local exploitation phase, different operators are well designed for the two sub-populations to generate neighbor individuals and a local search strategy based on critical path is proposed to enhance the exploitation ability. In addition, the influence of parameters is investigated based on Taguchi method of design of experiment, and a suitable parameter setting is determined. Finally, numerical simulation based on some widely used benchmark instances is carried out. The comparisons between BEDA and some existing algorithms as well as the single-population based EDA demonstrate the effectiveness of the proposed BEDA in solving the FJSP. (C) 2011 Elsevier Ltd. All rights reserved.

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# Learnable tabu search guided by estimation of distribution for maximum diversity problems

Wang, Jiahai Zhou, Ying Cai, Yiqiao Yin, Jian

This paper presents a learnable tabu search (TS) guided by estimation of distribution algorithm (EDA), called LTS-EDA, for maximum diversity problem. The LTS-EDA introduces knowledge model and can extract knowledge during the search process of TS, and thus it adopts dual or cooperative evolution/search structure, consisting of probabilistic model space in clustered EDA and solution space searched by TS. The clustered EDA, as a learnable constructive method, is used to create a new starting solution, and the simple TS, as an improvement method, attempts to improve the solution created by the clustered EDA in the LTS-EDA. A distinguishing feature of the LTS-EDA is the usage of the clustered EDA with effective linkage learning to guide TS. In the clustered EDA, different clusters (models) focus on different substructures, and the combination of information from different clusters (models) effectively combines substructures. The LTS-EDA is tested on 50 large size benchmark problems with the size ranging from 2,000 to 5,000. Simulation results show that the LTS-EDA is better than the advanced algorithms proposed recently.

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# An effective hybrid EDA-based algorithm for solving multidimensional knapsack problem

Wang, Ling Wang, Sheng-yao Xu, Ye

In this paper, an effective hybrid algorithm based on estimation of distribution algorithm (EDA) is proposed to solve the multidimensional knapsack problem (MKP). With the framework of EDA, the probability model is built with the superior population and the new individuals are generated based on probability model. In addition, an updating mechanism of the probability model is proposed and a mechanism for initializing the probability model based on the specific knowledge of the MKP is also proposed to improve the convergence speed. Meanwhile, an adaptive local search is proposed to enhance the exploitation ability. Furthermore, the influences of parameters are investigated based on Taguchi method of design of experiment and the importance of repair operator is also studied via simulation testing and comparisons. Finally, numerical simulation is carried out based on the benchmark instances, and the comparisons with some existing algorithms demonstrate the effectiveness of the proposed algorithm. (C) 2011 Elsevier Ltd. All rights reserved.

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# Entropy-based efficiency enhancement techniques for evolutionary algorithms

Hoang Ngoc Luong Hai Thi Thanh Nguyen Ahn, Chang Wook

This paper introduces the notion of an entropy measurement for populations of candidate solutions in evolutionary algorithms, developing both conditional and joint entropy-based algorithms. We describe the inherent characteristics of the entropy measurement and how these affect the search process. Following these discussions, we develop a recognition mechanism through which promising candidate solutions can be identified without the need of invoking costly evaluation functions. This on-demand evaluation strategy (ODES) is able to perform decision making tasks regardless of whether the actual fitness evaluation is necessary or not, making it an ideal efficiency enhancement technique for accelerating the computational process of evolutionary algorithms.

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# An estimation of distribution algorithm for lot-streaming flow shop problems with setup times

Pan, Quan-Ke Ruiz, Ruben

Lot-streaming flow shops have important applications in different industries including textile, plastic, chemical, semiconductor and many others. This paper considers an n-job m-machine lot-streaming flow shop scheduling problem with sequence-dependent setup times under both the idling and no-idling production cases. The objective is to minimize the maximum completion time or makespan. To solve this important practical problem, a novel estimation of distribution algorithm (EDA) is proposed with a job permutation based representation. In the proposed EDA, an efficient initialization scheme based on the NEH heuristic is presented to construct an initial population with a certain level of quality and diversity. An estimation of a probabilistic model is constructed to direct the algorithm search towards good solutions by taking into account both job permutation and similar blocks of jobs. A simple but effective local search is added to enhance the intensification capability. A diversity controlling mechanism is applied to maintain the diversity of the population. In addition, a speed-up method is presented to reduce the computational effort needed for the local search technique and the NEH-based heuristics. A comparative evaluation is carried out with the best performing algorithms from the literature. The results show that the proposed EDA is very effective in comparison after comprehensive computational and statistical analyses. (C) 2011 Elsevier Ltd. All rights reserved.

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# Performance Evaluation of an EDA-Based Large-Scale Plug-In Hybrid Electric Vehicle Charging Algorithm

Su, Wencong Chow, Mo-Yuen

The anticipation of a large penetration of plug-in hybrid electric vehicles (PHEVs) into the market brings up many technical problems that need to be addressed. In the near future, a large number of PHEVs in our society will add a large-scale energy load to our power grids, as well as add substantial energy resources that can be utilized. An emerging issue is that a large number of PHEVs simultaneously connected to the grid may pose a huge threat to the overall power system quality and stability. In this paper, the authors propose an algorithm for optimally managing a large number of PHEVs (e.g., 3000) charging at a municipal parking station. The authors used the estimation of distribution algorithm (EDA) to intelligently allocate electrical energy to the PHEVs connected to the grid. A mathematical framework for the objective function (i.e., maximizing the average state-of-charge at the next time step) is also given. The authors considered real-world constraints such as energy price, remaining battery capacity, and remaining charging time. The authors also simulated the real-world parking deck scenarios according to the statistical analysis based on the transportation data. The authors characterized the performance of EDA using a Matlab simulation, and compared it with other optimization techniques.

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# A hybrid estimation of distribution algorithm for solving the resource-constrained project scheduling problem

Wang, Ling Fang, Chen

In this paper, a hybrid estimation of distribution algorithm (HEDA) is proposed to solve the resource-constrained project scheduling problem (RCPSP). In the HEDA, the individuals are encoded based on the extended active list (EAL) and decoded by serial schedule generation scheme (SGS), and a novel probability model updating mechanism is proposed for well sampling the promising searching region. To further improve the searching quality, a Forward-Backward iteration (FBI) and a permutation based local search method (PBLS) are incorporated into the EDA based search to enhance the exploitation ability. Simulation results based on benchmarks and comparisons with some existing algorithms demonstrate the effectiveness of the proposed HEDA. (C) 2011 Elsevier Ltd. All rights reserved.

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# Gaussian process assisted coevolutionary estimation of distribution algorithm for computationally expensive problems

Luo Na Qian Feng Zhao Liang Zhong Wei-min

In order to reduce the computation of complex problems, a new surrogate-assisted estimation of distribution algorithm with Gaussian process was proposed. Coevolution was used in dual populations which evolved in parallel. The search space was projected into multiple subspaces and searched by sub-populations. Also, the whole space was exploited by the other population which exchanges information with the sub-populations. In order to make the evolutionary course efficient, multivariate Gaussian model and Gaussian mixture model were used in both populations separately to estimate the distribution of individuals and reproduce new generations. For the surrogate model, Gaussian process was combined with the algorithm which predicted variance of the predictions. The results on six benchmark functions show that the new algorithm performs better than other surrogate-model based algorithms and the computation complexity is only 10% of the original estimation of distribution algorithm.

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# An Improved Population-Based Incremental Learning Method for Objects Buried in Planar Layered Media

Chen, Xiaoming Lei, Gang Yang, Guangyuan Shao, K. R. Guo, Youguang Zhu, Jianguo Lavers, J. D.

An evolutionary algorithm, the estimation of distribution algorithm (EDA), is used to reconstruct the objects that buried in planar layered media. It is essential that fast forward solvers be used to solve the forward scattering problem for the nonlinear inverse scattering methods, since it can avoid errors by approximation. The EDA is a predominant all-round optimizing method in the macroscopic simulation of evolution process species of nature. Recent studies have shown that the EDA provides better solution for nonlinear problems than the microscopic evolutionary algorithm, such as genetic algorithm (GA) in some cases. The EDA is simpler, both computationally and theoretically, than the GA. We discuss how this can be used to calculate the permittivity and conductivity of the targets. We show preliminary results indicating the potential of reconstruction for buried objects. Compared with other methods, the experiment result shows that the EDA algorithm reduces the number of iteration.

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# An effective estimation of distribution algorithm for the multi-mode resource-constrained project scheduling problem

Wang, Ling Fang, Chen

In this paper, an estimation of distribution algorithm (EDA) is proposed to solve the multi-mode resource-constrained project scheduling problem (MRCPSP). In the EDA, the individuals are encoded based on the activity-mode list (AML) and decoded by the multi-mode serial schedule generation scheme (MSSGS), and a novel probability model and an updating mechanism are proposed for well sampling the promising searching region. To further improve the searching quality, a multi-mode forward backward iteration (MFBI) and a multi-mode permutation based local search method (MPBLS) are proposed and incorporated into the EDA based search framework to enhance the exploitation ability. Based on the design-of-experiment (DOE) test, suitable parameter combinations are determined and some guidelines are provided to set the parameters. Simulation results based on a set of benchmarks and comparisons with some existing algorithms demonstrate the effectiveness of the proposed EDA. (C) 2011 Elsevier Ltd. All rights reserved.

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# Genetic & Evolutionary Biometrics: Feature Extraction from a Machine Learning Perspective

Shelton, Joseph Alford, Aniesha Small, Lasanio Leflore, Derrick Williams, Jared Adams, Joshua Dozier, Gerry Bryant, Kelvin Abegaz, Tamirat Ricanek, Karl

Genetic &amp; Evolutionary Biometrics (GEB) is a newly emerging area of study devoted to the design, analysis, and application of genetic and evolutionary computing to the field of biometrics. In this paper, we present a GEB application called GEFEML (Genetic and Evolutionary Feature Extraction Machine Learning). GEFEML incorporates a machine learning technique, referred to as cross validation, in an effort to evolve a population of local binary pattern feature extractors (FEs) that generalize well to unseen subjects. GEFEML was trained on a dataset taken from the FRGC database and generalized well on two test sets of unseen subjects taken from the FRGC and MORPH databases. GEFEML evolved FEs that used fewer patches, had comparable accuracy, and were 54% less expensive in terms of computational complexity.

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# A Hybrid Adaptive Evolutionary Algorithm in the Domination-based and Decomposition-based Frameworks of Multi-objective Optimization

Shim, V. A. Tan, K. C. Tan, K. K.

Under the framework of evolutionary paradigms, many variations of evolutionary algorithms have been designed. Each of the algorithms performs well in certain cases and none of them are dominating one another. This study is based on the idea of synthesizing different evolutionary algorithms so as to complement the limitations of each algorithm. On top of this idea, this paper proposes an adaptive mechanism that synthesizes a genetic algorithm, differential evolution and estimation of distribution algorithm. The adaptive mechanism takes into account the ratio of the number of promising solutions generated from each optimizer in an early stage of evolutions so as to determine the proportion of the number of solutions to be produced by each optimizer in the next generation. Furthermore, the adaptive algorithm is also hybridized with the evolutionary gradient search to further enhance its search ability. The proposed hybrid adaptive algorithm is developed in the domination-based and decomposition-based multi-objective frameworks. An extensive experimental study is carried out to test the performances of the proposed algorithms in 38 state-of-the-art benchmark test instances.

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# Use of Graph Kernels in Estimation of Distribution Algorithms

Handa, Hisashi

The graph-related problems, which solutions are represented by graphs, have attracted much attention since there are a large number of application areas in bioinformatics and social science. In this paper, we propose a novel Estimation of Distribution Algorithm which can effectively cope with graphs. The proposed method employs graph kernels in estimation and sampling phases in the EDAs. The preliminary experiments on edge-max problems and edge-min problems elucidate the effectiveness of the proposed method.

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# AutoClustering An Estimation of Distribution Algorithm for the Automatic Generation of Clustering Algorithms

Meiguins, Aruanda S. G. Limao, Roberto C. Meiguins, Bianchi S. Junior, Samuel F. S. Freitas, Alex A.

Most of the existing Data Mining algorithms have been manually produced, that is, have been developed by a human programmer. A prominent Artificial Intelligence research area is automatic programming - the generation of a computer program by another computer program. Clustering is an important data mining task with many useful real-world applications. Particularly, the class of clustering algorithms based on the idea of data density to identify clusters has many advantages, such as the ability to identify arbitrary-shape clusters. We propose the use of Estimation of Distribution Algorithms for the artificial generation of density-based clustering algorithms. In order to guarantee the generation of valid algorithms, a directed acyclic graph (DAG) was defined where each node represents a procedure (building block) and each edge represents a possible execution sequence between two nodes. The Building Blocks DAG specifies the alphabet of the EDA, that is, any possibly generated algorithm. Preliminary experimental results compare the clustering algorithms artificially generated by AutoClustering to DBSCAN, a well-known manually-designed algorithm.

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# Maximizing the Number of Polychronous Groups in Spiking Networks

Santana, Roberto Bielza, Concha Larranaga, Pedro

In this paper we investigate the effect of biasing the axonal connection delay values in the number of polychronous groups produced for a spiking neuron network model. We use an estimation of distribution algorithm (EDA) that learns tree models to search for optimal delay configurations. Our results indicate that the introduced approach can be used to considerably increase the number of such groups.

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# Evolving NK-complexity for Evolutionary Solvers

Santana, Roberto Mendiburu, Alexander Lozano, Jose A.

In this paper we empirically investigate the structural characteristics that can help to predict the complexity of NK-landscape instances for estimation of distribution algorithms (EDAs). We evolve instances that maximize the EDA complexity in terms of its success rate. Similarly, instances that minimize the algorithm complexity are evolved. We then identify network measure, computed from the structures of the NK-landscape instances, that have a statistically significant difference between the set of easy and hard instances. The features identified are consistently significant for different values of N and K.

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# A Linkage-Learning Niching in Estimation of Distribution Algorithm

Ho, Tsung-Yu Yu, Tian-Li

This work proposes a linkage-learning nicking method that improves the capability of estimation of distribution algorithms (EDAs) on reducing spurious linkages which increase problems difficulty. Concatenated parity function (CPF), a class of allelic pairwise independent problems, causes exponential scalability for hierarchical Bayesian optimization algorithm (hBOA), which is one of powerful EDAs. Empirical results show that restricted tournament replacement (RTR) that hBOA employs results in spurious linkages and increases difficulty on solving CPF. Our research consists of these goals: (1) proposing a mutual information matrix to approximate the implicit linkage-information during EDAs' execution, (2) reducing spurious linkages by utilizing new metric of similarity, and (3) maintaining diversity of population. The results show that hBOA with our proposed nicking method reduces the spurious linkages and solves CPF in the polynomial time.

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# A decision support system with EDA\_PR algorithm for the hot rolling scheduling

Zhang, Xiaoxia Ma, Yunyong

This paper presents a hybrid algorithm for the hot rolling scheduling problem, which is derived from the actual steel production, and some features make the solution methodology more difficult. The hybrid strategy is based on the solution construction mechanism of estimation of distribution algorithm (EDA) with path relinking (PR), an evolutionary method, which results in a novel approach that we call EDA\_PR. Moreover, a decision support system in which the algorithm has been embedded for the hot rolling scheduling is designed. The computational experiments show that the EDA\_PR method has more potential for improvement to solve the hot rolling scheduling problem compared with the manual scheduling method.

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# Solving Sudoku with Bayesian Optimization Algorithm

Shirakami, Shinichi Sato, Yuji

Recently, the Estimation of distribution algorithm (EDA) has been studied as a measure to solve the problem that the Genetic algorithm (GA) destroys effective building blocks. The Bayesian optimization algorithm ( BOA) that is one of EDAs evolves a population of candidate solutions by building and sampling Bayesian networks. However, the BOA has some problems, for example the processing time is too longer. In this paper, we use the Sudoku puzzle that is one of the real problems, focusing on the problem of processing time and convergence to local solution. We propose the method defined chromosome combined nine candidate regions would make it possible to compress the search spaces. We evaluate this method by using two types of Sudoku puzzles and comparing result of the method that defines a one-dimensional chromosome that has a total length of at most 324 binary numbers and converts binary numbers into integer numbers to the result of our proposal method. In the result, our proposal method reduces processing time and amount of generations than the original program and performs as precision as the original program.

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# Global Optimal Selection of Web Composite Services Based on UMDA

Cheng, Shuping Lu, Xiaoming Zhou, Xianzhong

QoS model of composite services and Web services selection based on QoS are currently the hot issues in the web service composition area. Services selection based on QoS, which is a global optimal selection issue, has been proved a NP-HARD problem. Takes engine into account, this paper builds the QoS model of service selection in the Web composite services, uses the estimation of distribution algorithm to solve the NP-HARD problem of services selection, and presents a Web services selection method based on the UMDA. Example analysis and experimental analysis based on the UMDA method are performed; it's proved that the method is effective in solving the NP-HARD problem of Web services selection.

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# An EDA Based on Bayesian Networks Constructed with Archimedean Copulas

Flores Mendez, Mario Rogelio Landa, Ricardo

In this paper, an estimation of distribution algorithm that adopts a copula Bayesian network as probabilistic graphic model is presented. Multivariate Archimedean copula functions with one parameter are used to model the dependences between variables and the beta distribution is used to describe the univariate marginals. The learning process of the Bayesian network is assisted through a simple technique that relies on the associative property of Archimedean copulas, the use of Kendall's tau coefficient for measuring relations between variables and the relation between tau coefficients and bivariate Archimedean copulas. This paper presents the proposal, together with some initial experiments, which show encouraging results.

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# LEARNING TO PLAY <i>K</i>-ARMED BANDIT PROBLEMS

Maes, Francis Wehenkel, Louis Ernst, Damien

We propose a learning approach to pre-compute K-armed bandit playing policies by exploiting prior information describing the class of problems targeted by the player. Our algorithm first samples a set of K-armed bandit problems from the given prior, and then chooses in a space of candidate policies one that gives the best average performances over these problems. The candidate policies use an index for ranking the arms and pick at each play the arm with the highest index; the index for each arm is computed in the form of a linear combination of features describing the history of plays (e.g., number of draws, average reward, variance of rewards and higher order moments), and an estimation of distribution algorithm is used to determine its optimal parameters in the form of feature weights. We carry out simulations in the case where the prior assumes a fixed number of Bernoulli arms, a fixed horizon, and uniformly distributed parameters of the Bernoulli arms. These simulations show that learned strategies perform very well with respect to several other strategies previously proposed in the literature (UCB1, UCB2, UCB-V, KL-UCB and epsilon(n)-GREEDY); they also highlight the robustness of these strategies with respect to wrong prior information

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# Intelligent PHEV Charging and Discharging Strategy in Smart Grid

Yu, Jie Gu, Wei Wu, Zaijun

The anticipation of a large penetration of Plug-in Hybrid Electric Vehicles (PHEVs) and Plug-in Electric Vehicles (PEVs) into the market brings up many new technical problems that need to be addressed. In the near future, a large number of PHEVs/PEVs connected to power grids will add a large-scale energy load, as well as add substantial energy resources that can be utilized. Vehicle-to-Grid (V2G) technology is a most promising opportunity in PHEV/PEV adoption. In this paper, the authors propose an intelligent method for optimally managing a large number of PHEVs/PEVs (e. g., 3,000) charging/discharging at a municipal parking deck. The authors used the Estimation of Distribution Algorithm (EDA) to determine the optimal charging/discharging times and patterns over a period of 24 hours. A mathematical framework for the objective function (i.e., maximizing the overall profit on a vehicle fleet base) is also given in detail. The authors characterized the performance of EDA-based energy management using a Matlab simulation, and compared it with other optimization techniques.

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# Pareto-Based Multi-objective Estimation of Distribution Algorithm with Gaussian Copulas and Application in RFID Network Planning

Gao, Ying Peng, Lingxi Li, Fufang Liu, Miao Hu, Xiao

A Pareto-based multi-objective estimation of distribution algorithm with Gaussian copulas is proposed and applied to RFID network planning. The algorithm employs Pareto-based approach and multivariate Gaussian copulas to construct probability distribution model. By estimating Kendall's tau and using the relationship of Kendall's tau and correlation matrix, Gaussian copula parameters are firstly estimated, thus, joint distribution is estimated. Afterwards, the Monte Carte simulation is used to generate new individuals. An archive with maximum capacity is used to maintain the non-dominated solutions. The Pareto optimal solutions are selected from the archive on the basis of the diversity of the solutions, and the crowding-distance measure is used for the diversity measurement. The archive gets updated with the inclusion of the non-dominated solutions from the combined population and current archive, and the archive which exceeds the maximum capacity is cut using the diversity consideration. The proposed algorithm is applied to some benchmark and RFID network planning. The relative experimental results show that the algorithm has better performance and is effective.

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# Vine Estimation of Distribution Algorithms with Application to Molecular Docking

Soto, Marta Ochoa, Alberto Gonzalez-Fernandez, Yasser Milanes, Yanely Alvarez, Adriel Carrera, Diana Moreno, Ernesto

Abstract no encontrado

[Paper](https://www.webofscience.com/api/gateway?GWVersion=2&SrcApp=edas&SrcAuth=WosAPI&KeyUT=WOS:000324600300014&DestLinkType=FullRecord&DestApp=WOS_CPL)

# EDA-RL: EDA with Conditional Random Fields for Solving Reinforcement Learning Problems

Handa, Hisashi

This chapter introduces a novel Estimation of Distribution Algorithm for solving Reinforcement Learning Problems, i.e., EDA-RL. As the probabilistic model of the EDA-RL, the Conditional Random Fields proposed by Lafferty et al. are employed. The Conditional Random Fields can estimate conditional probability distributions by using Markov Network. Moreover, the structural search of probabilistic model by using x(2)-test, and data correction method are examined. One of the primary features of the EDA-RL is the direct estimation of reinforcement learning agents' policies by using the Conditional Random Fields. Another feature is that a kind of undirected graphical probabilistic model is used in the proposed method. The experimental results on Probabilistic Transition Problems and Maze Problems show the effectiveness of the EDA-RL.

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# MN-EDA and the Use of Clique-Based Factorisations in EDAs

Santana, Roberto

This chapter discusses the important role played by factorisations in the study of EDAs and presents the Markov network estimation of distribution algorithm (MN-EDA) as a classical example of the EDAs based on the use of undirected graphs. The chapter also reviews recent work on the use of clique-based decompositions and other approximations methods inspired in the field of statistical physics with direct application to EDAs.

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# An Estimation of Distribution Algorithm for Solving the Quay Crane Scheduling Problem with Availability Constraints

Exposito Izquierdo, Christopher Melian Batista, Belen Marcos Moreno Vega, J.

This work addresses the Quay Crane Scheduling Problem under availability constraints, whose main goal is to determine the work schedules of the quay cranes allocated to a container vessel in order to carry out its transhipment operations (loading and unloading operations). An Estimation of Distribution Algorithm with shaking procedure is proposed to solve it. The position of the tasks and the operative areas of quay cranes are considered in the initialization step in order to reach high-quality regions of the search space. Computational experiments show that this method improves previous state-of-art approaches.

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# Estimation of Distribution Algorithm for Green Resource Allocation in Cognitive Radio Systems

Naeem, Muhammad Ashrafinia, Saeed Lee, Daniel

In this paper, we formulate a resource allocation optimization problem for a cooperative relay-assisted cognitive radio system, comprising a single source node, multiple relays and multiple destinations. Our formulation takes into account the effects of the resource allocation on CO2 emission, and we refer to it as a green resource allocation problem. The green resource allocation problem is formulated as a non-linear multi-objective optimization problem. We modify the objective function by applying the weighted sum method, which results in a non-convex mixed integer non-linear programming problem. We propose a hybrid evolutionary scheme that utilizes an enhanced version of Estimation of Distributions Algorithm to solve this optimization problem. Simulation results demonstrate the efficiency of our evolutionary algorithm approach in comparison to other schemes such as GA and EDA.

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# Modified Bayesian Optimization Algorithm for EMC Complex System Design

Bui Van Ha Maglio, M. M. Mussetta, M. Pirinoli, P. Zich, R. E.

The design of real electrical, electronic or electromagnetic complex systems fulfilling EMC constrains often exploits the performances of population based global optimizers. One of the main drawbacks of the adoption of these optimizers in the design of a real system is the difficulty in the introduction, in the optimized design algorithm, of all the heuristic knowledge already available in the field. In order to overcome this problem Bayesian optimization algorithms, classified as estimation of distribution algorithm, could be very effective, since they are based on the definition of the distribution of promising solutions by using the information extracted from the entire set of currently good solutions. Unfortunately, their straightforward implementations usually lack of exploration, and are easily trapped in local maxima. In order to overcome even this drawback and to develop a Bayesian optimization algorithm with both the required exploitation, of the heuristic knowledge, and the exploration, for avoiding local maxima, for system or subsystem design fulfilling EMC constrains, in this paper a modified BOA is proposed by adding a suitable mutation scheme to the traditional one in order to ensure the effectiveness of the algorithm. The here proposed new algorithm has been tested on some mathematical test functions and on a typical EM design problem, a microwave microstrip filter synthesis, to show its capability.

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# Mutation in Compressed Encoding in Estimation of Distribution Algorithm

Watchanupaporn, Orawan Suwannik, Worasait Chongstitvatana, Prabhas

Estimation of Distribution Algorithm (EDA) is a new kind of evolutionary algorithm. However, it does not use evolutionary operators such as crossover and mutation. In this paper, we investigate how mutation has an effect on the performance of EDA, more specifically, compact genetic algorithm (cGA) and LZWcGA; the latter uses compressed encoding. The result shows that cGA performs poorly with mutation while LZWcGA's performance is improved by mutation. We also present an analysis of mutation in both algorithms.

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# Asynchronous Strategy of Parallel Hybrid Approach of GA and EDA for Function Optimization

Said, Said Mohamed Nakamura, Morikazu

This paper adapts parallel master-slave estimation of distribution and genetic algorithms (GAs and EDAs) hybridization. The master selects portions of the search space, and slaves perform, in parallel and independently, a GA that solves the problem on the assigned portion of the search space. The master's work is to progressively narrow the areas explored by the slave's GAs, using parallel dynamic K-means clustering to determine the basins of attraction of the search space. Coordination of activities between master and slaves is done in an asynchronous way (i.e. no waiting is entertained among the processes). The proposed asynchronous model has managed to reduce computation time while maintaining the quality of solutions.

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# An Estimation of Distribution Algorithm with Efficient Constructive Repair/Improvement Operator for the Dynamic Weapon-Target Assignment

Xin Bin Chen Jie

This paper reports our recent research about new efficient problem-solvers for the dynamic weapon-target assignment (DWTA). A binary-encoding-based estimation of distribution algorithm (EDA) is proposed to solve DWTA problems. An elaborate constructive repair/improvement (CRI) operator is proposed and integrated into the EDA to achieve constraint saturation, which conduces to constraint satisfaction as well as the improvement of generated solutions. The performance comparison against another two EDAs which employ well-known constraint handling methods demonstrates the superiority of the CRI operator. The proposed EDA based on the CRI operator also shows very competitive and even better performance against several state-of-the-art DWTA algorithms.

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# Task Allocation for Multi-Satellite Cooperation Based on Estimation of Distribution Algorithm

Wang Shi-xing Wu Jin-hua Tian Liang

One task allocation for multi-satellite cooperation with two layers is proposed in this paper during the long-range orbit transfer with two impulses. The low layer considers the time and energy consumption during the transfer and the estimation of distribution algorithm (EDA) is adopted to solve the optimization in continuous domain. The high layer gives the multi-platform task allocation model by analyzing target value and time-energy consumption. Decision variables in discrete domain are optimized based on EDA. Simulation study on different mission mode proved the effectiveness of them strategy based on EDA.

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# A Continuous Estimation of Distribution Algorithm by Evolving Graph Structures Using Reinforcement Learning

Li, Xianneng Li, Bing Mabu, Shingo Hirasawa, Kotaro

A novel graph-based Estimation of Distribution Algorithm (EDA) named Probabilistic Model Building Genetic Network Programming (PMBGNP) has been proposed. Inspired by classical EDAs, PMBGNP memorizes the current best individuals and uses them to estimate a distribution for the generation of the new population. However, PMBGNP can evolve compact programs by representing its solutions as graph structures. Therefore, it can solve a range of problems different from conventional ones in EDA literature, such as data mining and Reinforcement Learning (RL) problems. This paper extends PMBGNP from discrete to continuous search space, which is named PMBGNP-AC. Besides evolving the node connections to determine the optimal graph structures using conventional PMBGNP, Gaussian distribution is used for the distribution of continuous variables of nodes. The mean value mu and standard deviation sigma are constructed like those of classical continuous Population-based incremental learning (PBILc). However, a RL technique, i.e., Actor-Critic (AC), is designed to update the parameters (mu and sigma). AC allows us to calculate the Temporal-Difference (TD) error to evaluate whether the selection of the continuous value is better or worse than expected. This scalar reinforcement signal can decide whether the tendency to select this continuous value should be strengthened or weakened, allowing us to determine the shape of the probability density functions of the Gaussian distribution. The proposed algorithm is applied to a RL problem, i.e., autonomous robot control, where the robot's wheel speeds and sensor values are continuous. The experimental results show the superiority of PMBGNP-AC comparing with the conventional algorithms.

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# A Hybrid Estimation of Distribution Algorithm for Solving the Multi-objective Multiple Traveling Salesman Problem

Shim, V. A. Tan, K. C. Tan, K. K.

The multi-objective multiple traveling salesman problem (MmTSP) is a generalization of the classical multi-objective traveling salesman problem. In this paper, a formulation of the MmTSP, which considers the weighted sum of the total traveling costs of all salesmen and the highest traveling cost of any single salesman, is proposed. An estimation of distribution algorithm (EDA) based on restricted Boltzmann machine is used for solving the formulated problem. The EDA is developed in the decomposition framework of multi-objective optimization. Due to the limitation of EDAs in generating a wide range of solutions, the EDA is hybridized with the evolutionary gradient search. Simulation studies are carried out to examine the optimization performances of the proposed algorithm on MmTSP with different number of objective functions, salesmen and problem sizes.

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# An analysis of the use of probabilistic modeling for synaptic connectivity prediction from genomic data

Santana, Roberto Mendiburu, Alexander Lozano, Jose A.

The identification of the specific genes that influence particular phenotypes is a common problem in genetic studies. In this paper we address the problem of determining the influence of gene joint expression in synapse predictability. The question is posed as an optimization problem in which the conditional entropy of gene subsets with respect to the synaptic connectivity phenotype is minimized. We investigate the use of single- and multi-objective estimation of distribution algorithms and focus on real data from C. elegans synaptic connectivity. We show that the introduced algorithms are able to compute gene sets that allow an accurate synapse predictability. However, the multi-objective approach can simultaneously search for gene sets with different number of genes. Our results also indicate that optimization problems defined on constrained binary spaces remain challenging for the conception of competitive estimation of distribution algorithm.

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# The Experimental Study of Population-based Parameter Optimization Algorithms on Rule-based Ecological Modelling

Cao, Hongqing Recknagel, Friedrich Orr, Philip T.

This study investigates six population-based algorithms for the parameter optimization (PO) within the hybrid methodology developed for modelling algal abundance by rule-based models. These PO algorithms include: (1) Hill Climbing (2) Simulated Annealing (3) Genetic Algorithm (4) Differential Evolution (5) Covariance Matrix Adaptation Evolution Strategy and (6) Estimation of Distribution Algorithm. The effectiveness of algorithms is tested on the Cylindrospermopsis abundance data from Wivenhoe Reservoir in Queensland (Australia). We provide a systematic analysis and comparison of different parameter optimization algorithms as well as the resulting predictive rule models.

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# A Compact Estimation of Distribution Algorithm for Solving Hybrid Flow-shop Scheduling Problem

Wang, Shengyao Wang, Ling Xu, Ye

According to the characteristics of the hybrid flow-shop scheduling problem (HFSP), the permutation based encoding and decoding schemes are designed and a probability model for describing the distribution of the solution space is built to propose a compact estimation of distribution algorithm (cEDA) in this paper. The algorithm uses only two individuals by sampling based on the probability model and updates the parameters of the probability model with the selected individual. The cEDA is efficient and easy to implement due to its low complexity and comparatively few parameters. Simulation results based on some widely-used instances and comparisons with some existing algorithms demonstrate the effectiveness and efficiency of the proposed compact estimation of distribution algorithm. The influence of the key parameter on the performance is investigated as well.

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# The Optimization of Fuzzy Rules Based on Hybrid Estimation of Distribution Algorithms

Luo, Xiong Bai, Xue

Optimization of fuzzy rules based on numerical data is an important issue in the optimization design of fuzzy system. In this paper, based on an improved estimation of distribution algorithm, an optimization learning method COR\_MUMDA for fuzzy rules is proposed. This method can generate fuzzy rules directly from numerical data. The method learn fuzzy rules mainly based on MUMDA (multi-group univariate marginal distribution estimation algorithm). Unlike the general estimation of distribution algorithms, MUMDA can increase the diversity of the population and avoid sticking at local optima. In addition, the elite genetic strategy is used to generate the next population. In this way, it reduces the possibility of losing the optimal solutions. To verify the efficiency of this algorithm, the simulation experiments are performed. The comparative results of three classic examples are given.

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# Redundancy Allocation problem for a Series-Parallel system using Estimation of Distribution Algorithm

Melo, Haydee Junzo, Watada

Reliability is an engineering field that recently has captivated the attention of researches. Its goal is to develop new techniques to improve the security and performance of the systems. The increasing complexity in the systems as a result of growing technology makes them more susceptible for failures. In the redundancy allocation problem (RAP) its principal objective is to maximize the availability while reducing the cost, volume or weight of the system. In this research an Estimation-of-Distribution Algorithm (EDA) approach is proposed for solving the redundancy allocation problem for a series-parallel system.

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# A Bio Inspired Estimation of Distribution Algorithm for Global Optimization

Soliman, Omar S. Rassem, Aliaa

This paper introduces a new bio-inspired Estimation of Distribution Algorithm for global optimization that integrates the quantum computing concepts with the immune clonal selection, vaccination process and Estimation of Distribution Algorithm (EDA). EDA is employed in the vaccination process to improve the solutions diversity and maintain high quality solutions in addition to its ability to avoid falling in local optimum for multi modal problems. The proposed algorithm is implemented and evaluated using standard benchmark test problems. Experimental results are compared with the quantum inspired immune clonal algorithm (QICA) and the QICA-with vaccine algorithm, where the proposed algorithm is superior to both of them. The obtained results carried out, it is performing well in terms of the solutions quality and diversity, and it is superior to both of compared algorithms.

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# Using ARFIMA Model to Calculate and Forecast Realized Volatility of High Frequency Stock Market Index Data

Mai, Yulin Li, Xia Zhao, Jing Luo, Dengyue

The forecast precision of realized volatility can be affected by both measurement error and market microstructure error when we analyze volatility using high frequency data. This paper adopts the method of second moving average to balance these two errors and establishes ARFIMA model to study the distribution characteristics of realized volatility based on high frequency data of hushen300, its parameters are estimated applying estimation of distribution algorithm. Finally, the superiority of ARFIMA model in volatility forecast is proved by comparing the performances of ARFIMA model and GARCH model.

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# Improved Compact Genetic Algorithm for EM Complex System Design

Bui Van Ha Zich, R. E. Mussetta, M. Pirinoli, Paola Chien Ngoc Dao

Nowadays the design of complex real electrical, electronic or electromagnetic systems may effectively exploit the characteristics of population based global optimizers. One of the main drawbacks of the adoption of these optimizers in the design of a real system is the difficulty in the introduction, in the optimized design algorithm, of all the heuristic knowledge already available in the field. In order to overcome this problem compact genetic algorithms, classified as estimation of distribution algorithm, could be very effective, since they apply and manipulate a suitable probability vector to represent the distribution of good solutions. Unfortunately, their straightforward implementations usually lack of exploration, and they are easily trapped in local maxima. In order to overcome even this drawback and to develop a compact genetic algorithm with both the required exploitation, of the heuristic knowledge, and the exploration, for avoiding local maxima, in this paper a modified cGA is proposed by implementing more probability vectors and adding a suitable learning scheme to the traditional one in order to ensure the effectiveness of the algorithm. The here proposed new algorithm has been tested on some mathematical test functions and on a typical EM design problem, a microwave microstrip filter synthesis.

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# Modified Bayesian Optimization Algorithm for Planar Array Design

Bui Van Ha Mussetta, M. Grimaccia, F. Pirinoli, P. Zich, R. E.

Design of electrical and electronic systems with complex EMC constrains requires often to exploit the peculiarities of some population based global optimizers. One of the main drawbacks of the adoption of these optimizers for system design is represented by the difficulty of introducing in the algorithm all the heuristic knowledge already available in the field. In order to overcome this problem, Bayesian optimization algorithms (BOAs), classified as estimation of distribution algorithm, can be very effective since they are based on the definition of distributions of promising solutions using the information extracted from the entire set of good solutions. Unfortunately, their straightforward implementations usually lack of exploration feature and they are easily trapped in local maxima. In order to overcome this drawback and to develop a Bayesian optimization algorithm with both exploitation and exploration mechanisms, in this paper a modified BOA is proposed by adding a suitable mutation scheme to the traditional one in order to ensure the effectiveness of the algorithm. The here proposed new algorithm has been tested on different mathematical test functions and on a typical EM design problem, a planar array synthesis to show its performance.

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# Genetic & Evolutionary Biometrics: Hybrid Feature Selection and Weighting for a Multi-Modal Biometric System

Alford, Aniesha Steed, Crystal Jeffrey, Marcus Sweet, Donovan Shelton, Joseph Small, Lasanio Leflore, Derrick Dozier, Gerry Bryant, Kelvin Kelly, John C. Abegaz, Tamirat Ricanek, Karl

The Genetic &amp; Evolutionary Computation (GEC) research community is seeing the emergence of a new and exciting subarea, referred to as Genetic &amp; Evolutionary Biometrics (GEB), as GECs are increasingly being applied to a variety of biometric problems. In this paper, we present successful GEB techniques for multi-biometric fusion and multi-biometric feature selection and weighting. The first technique, known as GEF (Genetic &amp; Evolutionary Fusion), seeks to optimize weights for score-level fusion. The second technique is known as GEFeWSML (Genetic &amp; Evolutionary Feature Weighting and Selection-Machine Learning). The goal of GEFeWSML is to evolve feature masks (FMs) that achieve high recognition accuracy, use a low percentage of features, and generalize well to unseen subjects. GEFeWSML differs from the other GEB techniques for feature selection and weighting in that it incorporates cross validation in an effort to evolve FMs that generalize well to unseen subjects.

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# MODIFIED UNIVARIATE MARGINAL DISTIBUTION ALGORITHM COMBINATION WITH EXTREMAL OPTIMIZATION AND LEARNING AUTOMATA

Hashemi, Mitra Meybodi, Mohammad Reza

UMDA algorithm is a type of Estimation of Distribution Algorithms. This algorithm has better performance compared to others such as genetic algorithm in terms of speed, memory consumption and accuracy of solutions. It can explore unknown parts of search space well. It uses a probability vector and individuals of the population are created through the sampling. Furthermore, EO algorithm is suitable for local search of near global best solution in search space, and it does not stuck in local optimum. Hence, combining these two algorithms is able to create interaction between two fundamental concepts in evolutionary algorithms, exploration and exploitation, and achieve better results of this paper is used adaptive version of tau -EO algorithm called EO-LA. In this method the task of choosing a replacement component is assigned to Learning Automata. During the implementation of this algorithm, according to the suitability of produced solutions, feedback signals are sent to Learning Automata until adapt selected replacement component well. In this paper, results represent the better performance of the proposed algorithm (combination of three methods) on a Graph Bi-partitioning, NP-hard problem.

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# An Estimation of Distribution Algorithm for the Flexible Job-Shop Scheduling Problem

Wang, Shengyao Wang, Ling Zhou, Gang Xu, Ye

In this paper, an effective estimation of distribution algorithm (EDA) is proposed to solve the flexible job-shop scheduling problem with the criterion to minimize the maximum completion time (makespan). With the framework of the EDA, the probability model is built with the superior population and the new individuals are generated based on probability model. In addition, an updating mechanism of the probability model is proposed and a local search strategy based on critical path is designed to enhance the exploitation ability. Finally, numerical simulation is carried out based on the benchmark instances, and the comparisons with some existing algorithms demonstrate the effectiveness of the proposed algorithm.

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# A Modified Estimation of Distribution Algorithm for Digital Filter Design

Li, Yuquan Zhang, Gexiang Cheng, Jixiang Zeng, Xiangxiang Gheorghe, Marian Elias, Susan

Estimation of Distribution Algorithms (EDAs) are a class of probabilistic model-building evolutionary algorithms, which are characterized by learning and sampling the probability distribution of the selected individuals. This paper proposes a modified EDA (mEDA) for digital filter design. mEDA uses a novel sampling method, called centro-individual sampling, and a fuzzy C-means clustering technique to improve its performance. Extensive experiments conducted on a set of benchmark functions show that mEDA outperforms seven algorithms reported in the literature, in terms of the quality of solutions. Four types of digital infinite impulse response (IIR) filters are designed by using mEDA and the results show that mEDA can obtain better filter performance than four state-of-the-art methods.

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