# Approximating the Set of Pareto-Optimal Solutions in Both the Decision and Objective Spaces by an Estimation of Distribution Algorithm

Zhou, Aimin Zhang, Qingfu Jin, Yaochu

Most existing multiobjective evolutionary algorithms aim at approximating the Pareto front (PF), which is the distribution of the Pareto-optimal solutions in the objective space. In many real-life applications, however, a good approximation to the Pareto set (PS), which is the distribution of the Pareto-optimal solutions in the decision space, is also required by a decision maker. This paper considers a class of multiobjective optimization problems (MOPs), in which the dimensionalities of the PS and the PF manifolds are different so that a good approximation to the PF might not approximate the PS very well. It proposes a probabilistic model-based multiobjective evolutionary algorithm, called MMEA, for approximating the PS and the PF simultaneously for an MOP in this class. In the modeling phase of MMEA, the population is clustered into a number of subpopulations based on their distribution in the objective space, the principal component analysis technique is used to estimate the dimensionality of the PS manifold in each subpopulation, and then a probabilistic model is built for modeling the distribution of the Pareto-optimal solutions in the decision space. Such a modeling procedure could promote the population diversity in both the decision and objective spaces. MMEA is compared with three other methods, KP1, Omni-Optimizer and RM-MEDA, on a set of test instances, five of which are proposed in this paper. The experimental results clearly suggest that, overall, MMEA performs significantly better than the three compared algorithms in approximating both the PS and the PF.

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# Duple-EDA and sample density balancing

Cai YunPeng Xu Hua Sun XiaoMin Jia Peifa Liu Zehua

In this paper, a new method is proposed to overcome the problem of local optima traps in a class of evolutionary algorithms, called estimation of distribution algorithms (EDAs), in real-valued function optimization. The Duple-EDA framework is proposed in which not only the current best solutions but also the search history are modeled, so that long-term feedback can be taken into account. Sample Density Balancing (SDB) is proposed under the framework to alleviate the drift phenomenon in EDA. A selection scheme based on Pareto ranking considering both the fitness and the historical sample density is adopted, which prevents the algorithm from repeatedly sampling in a small region and directs it to explore potentially optimal regions, thus helps it avoid being stuck into local optima. An MBOA (mixed Bayesian optimization algorithm) version of the framework is implemented and tested on several benchmark problems. Experimental results show that the proposed method outperforms a standard niching method in these benchmark problems.

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# An estimation of distribution algorithm for minimizing the total flowtime in permutation flowshop scheduling problems

Jarboui, Bassem Eddaly, Mansour Siarry, Patrick

In this work we propose an estimation of distribution algorithm (EDA) as a new tool aiming at minimizing the total flowtime in permutation flowshop scheduling problems. A variable neighbourhood search is added to the algorithm as an improvement procedure after creating a new offspring. The experiments show that our approach outperforms all existing techniques employed for the problem and can provide new upper bounds. (C) 2008 Elsevier Ltd. All rights reserved.

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# Optimal Stabilizing Gain Selection for Networked Control Systems With Time Delays and Packet Losses

Li, Hongbo Chow, Mo-Yuen Sun, Zengqi

This brief addresses the optimal-stabilization problem for networked control systems (NCSs) with time delays and packet losses. The closed-loop NCS is modeled as a discrete-time switched system, and the stability conditions are derived in terms of linear matrix inequality. A controller design method with both system stability and control performance taken into account is proposed, and estimation of distribution algorithm is used to select the optimal stabilizing gain. The proposed method can be easily implemented to various applications, since it has simple structure and has no assumptions on time-delay and packet-loss models. Simulation and experimental results are given to demonstrate the effectiveness of the proposed approach.

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# Competitive Hopfield Network Combined With Estimation of Distribution for Maximum Diversity Problems

Wang, Jiahai Zhou, Yalan Yin, Jian Zhang, Yunong

This paper presents a discrete competitive Hopfield neural network (HNN) (DCHNN) based on the estimation of distribution algorithm (EDA) for the maximum diversity problem. In order to overcome the local minimum problem of DCHNN, the idea of EDA is combined with DCHNN. Once the network is trapped in local minima, the perturbation based on EDA can generate a new starting point for DCHNN for further search. It is expected that the further search is guided to a promising area by the probability model. Thus, the proposed algorithm can escape from local minima and further search better results. The proposed algorithm is tested on 120 benchmark problems with the size ranging from 100 to 5000. Simulation results show that the proposed algorithm is better than the other improved DCHNN such as multistart DCHNN and DCHNN with random flips and is better than or competitive with metaheuristic algorithms such as tabu-search-based algorithms and greedy randomized adaptive search procedure algorithms.

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# Latent Variable Model for Estimation of Distribution Algorithm Based on a Probabilistic Context-Free Grammar

Hasegawa, Yoshihiko Iba, Hitoshi

Estimation of distribution algorithms are evolutionary algorithms using probabilistic techniques instead of traditional genetic operators. Recently, the application of probabilistic techniques to program and function evolution has received increasing attention, and this approach promises to provide a strong alternative to the traditional genetic programming techniques. Although a probabilistic context-free grammar (PCFG) is a widely used model for probabilistic program evolution, a conventional PCFG is not suitable for estimating interactions among nodes because of the context freedom assumption. In this paper, we have proposed a new evolutionary algorithm named programming with annotated grammar estimation based on a PCFG with latent annotations, which allows this context freedom assumption to be weakened. By applying the proposed algorithm to several computational problems, it is demonstrated that our approach is markedly more effective at estimating building blocks than prior approaches.

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# Integrated feature and parameter optimization for an evolving spiking neural network: Exploring heterogeneous probabilistic models

Schliebs, Stefan Defoin-Platel, Michael Worner, Sue Kasabov, Nikola

This study introduces a quantum-inspired spiking neural network (QiSNN) as an integrated connectionist system, in which the features and parameters of an evolving spiking neural network are optimized together with the use of a quantum-inspired evolutionary algorithm. We propose here a novel optimization method that uses different representations to explore the two search spaces: A binary representation for optimizing feature subsets and a continuous representation for evolving appropriate real-valued configurations of the spiking network. The properties and characteristics of the improved framework are Studied on two different synthetic benchmark datasets. Results are compared to traditional methods, namely a multi-layer-perceptron and a naive Bayesian classifier (NBC). A previously used real world ecological dataset on invasive species establishment prediction is revisited and new results are obtained and analyzed by an ecological expert. The proposed method results in a much faster convergence to an Optimal Solution (or a close to it), in a better accuracy, and in a more informative set of features selected. (C) 2009 Elsevier Ltd. All rights reserved.

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# Optimization of Thorium loading in fresh core of Indian PHWR by evolutionary algorithms

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

This paper is concerned with the Indian design of a 220 MWe Pressurized Heavy Water Reactor having Natural Uranium fuel and heavy water as moderator and coolant. At the beginning of life, it is necessary to flatten the power by loading some Thorium bundles to achieve a nearly full power operation. The determination of best possible locations of Thorium bundles, which maximize fuel economy as well as safety, is a complex combinatorial optimization problem. About two decades ago, an optimum configuration of Thorium bundles was successfully arrived at by using a gradient based method and this pattern was actually loaded in the Indian PHWR at Kakrapar which went critical in 1992 [Balakrishnan, K., Kakodkar, A, 1994. Optimization of the initial fuel loading of the Indian PHWR with Thorium bundles for achieving full power. Annals of Nuclear Energy 21, 1-9]. Here, the same problem is revisited for two reasons. Firstly. computational techniques based on completely different philosophy namely "Genetic Algorithm" (GA) and "Estimation of Distribution Algorithm" (EDA) have been used. Secondly, the enormous increase in computing power during the last two decades is expected to provide a more exhaustive search. Indeed, it has been possible to find out many feasible Thorium configurations of comparable merit. Our results are similar with the result of the earlier BARC study but provide a range of additional configurations. As in earlier BARC work, we find that one can get from 95% to 97% full power without violating various safety aspects such as maximum bundle power, maximum channel power. channel outlet temperature and worth of the two shutdown systems. In the present work, the number of Thorium bundles which can be loaded range from 22 to 34. One of the outcomes of this study is that the computational techniques suitable for this type of problems have been identified and developed. Further studies involving the use of some other evolutionary methods and problems such as optimization of depleted Uranium loading are in progress. (C) 2009 Elsevier Ltd. All rights reserved.

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# Real options approach to evaluating genetic algorithms

Rimcharoen, Sunisa Sutivong, Daricha Chongstitvatana, Prabhas

The real options technique has emerged as an evaluation tool for investment under uncertainty. It explicitly recognizes future decisions, and the exercise strategy is based on the optimal decisions in future periods. This paper employs the optimal stopping policy derived from real options approach to analyze and evaluate genetic algorithms, specifically for the new branches namely Estimation of Distribution Algorithms (EDAs). As an example, we focus on their simple class called univariate EDAs, which include the population-based incremental learning (PBIL), the univariate marginal distribution algorithm (UMDA), and the compact genetic algorithm (cGA). Although these algorithms are classified in the same class, the characteristics of their optimal stopping policy are different. These observations are useful in answering the question "which algorithm is suitable for a particular problem''. The results from the simulations indicate that the option values can be used as a quantitative measurement for comparing algorithms. (C) 2008 Elsevier B.V. All rights reserved.

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# EDA-Based Speed Control of a Networked DC Motor System With Time Delays and Packet Losses

Li, Hongbo Chow, Mo-Yuen Sun, Zengqi

This paper presents a new controller design method for networked de motor system in the presence of time delays and packet losses. The sufficient condition under which the closed-loop system is asymptotically stable and the necessary condition under which the networked dc motor has zero steady-state tracking error are derived. Based on the obtained conditions, an output tracking controller design method is proposed, where the Estimation of Distribution Algorithm is used to optimize the control parameters to improve the system control performance. The proposed method can be easily applied to various applications, since it is simple and has no assumptions on time delay and packet loss models. Simulation and experimental results are given to demonstrate the effectiveness of the proposed approach.

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# Hybrid Estimation of Distribution Algorithm Using Local Function Approximations

Campelo, Felipe Guimaraes, Frederico G. Ramirez, Jaime A. Igarashi, Hajime

In this paper, we introduce an approach for the design of electromagnetic devices based on the use of Estimation of Distribution Algorithms (EDAs), coupled with approximation-based local search around the most promising solutions. The-main idea is to combine the power of EDAs in the solution of hard optimization problems with the faster convergence provided by the local search using local approximations. The resulting hybrid, algorithm is tested on a numerical benchmark problem.

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# HIGH-ORDER EDA

Zeng, Jin Ren, Qing-Sheng

In this paper, we investigate the usage of history information for estimation of distribution algorithm (EDA). In EDA, the distribution is estimated from a set of selected individuals and then the estimated distribution model is used to generate new individuals. It needs large population size to converge to the global optimum. A new algorithm, the high-order EDA, is proposed based on the idea of filter. By the usage of history information, it can converge to the global optimum with high probability even with small population size. Convergence properties are then discussed. We also show the application for constrained optimization problems.

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# An Estimation of Distribution Algorithm for Flowshop Scheduling with Limited Buffers

Eddaly, Mansour Jarboui, Bassem Siarry, Patrick Rebai, Abdelwaheb

Most of the works that address the flowshop scheduling problem presume unlimited buffers between successive machines. However, with the advent of new technologies in the manufacturing systems, limited capacity storage between machines has become profitable. Aimed at makespan minimization, the flowshop scheduling problem with buffer constraints is NP-hard in the strong sense. Therefore, several approximate algorithms have been proposed in the literature. In this chapter, we propose an Estimation of Distribution Algorithm for solving a flowshop scheduling problem with buffer constraints. The main characteristics of the problem, such as the order of jobs and similar blocks of jobs in the sequence, are taken into account while building the probabilistic model. In order to enrich the search procedure of the algorithm, a skewed variable neighbourhood search algorithm is embedded into it, restricted by a calculated probability which depends on the quality of the created offspring. The computational results show that our algorithm outperforms genetic algorithm and particle swarm algorithm, and can obtain several optimal solutions in a short time.

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# An Estimation of Distribution Algorithm for Minimizing the Makespan in Blocking Flowshop Scheduling Problems

Jarboui, Bassem Eddaly, Mansour Siarry, Patrick Rebai, Abdelwaheb

This chapter addresses to the blocking flowshop scheduling problem with the aim of minimizing the makespan. An Estimation of distribution Algorithm, followed by a local search procedure, after the step of creating a new individual, was developed in order to solve this problem. Our comparisons were performed against representative approaches proposed in the literature related to the blocking flowshop scheduling problem. The obtained results have shown that the proposed algorithm is able to improve 109 out of 120 best known solutions of Taillard's instances. Moreover, our algorithm outperforms all competing approaches in terms of solution quality and computational time.

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# A Hybrid Multi-objective Algorithm Using Genetic and Estimation of Distribution Based on Design of Experiments

Dai, Guangming Wang, Jianwen Zhu, Jiankai

In this paper, we design a hybrid multi-objective algorithm using genetic and estimation of distribution based on design of Experiments At first, we apply orthogonal design and uniform design to generate an initial population so that the population individual solutions scattered evenly in the feasible solutions space Second, we proposed a new convergence criterion to check whether the distribution of population has the obvious regularity When the population is convergence, we use the model-based method to reproduce new individual solutions, otherwise genetic operator was employed to generate offspring, The results of systematic experiments show that the hybrid algorithm this paper proposed capable of finding much better convergence near the Pareto-optimal solutions and better spread of solutions than RM-MEDA

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# Theoretical and Empirical Analysis of a GPU based Parallel Bayesian Optimization Algorithm

Munawar, Asim Wahib, Mohamed Munetomo, Masaharu Akama, Kiyoshi

General Purpose computing over Graphical Processing Units (GPGPUs) is a huge shift of paradigm in parallel computing that promises a dramatic increase in performance. But GPGPUs also bring an unprecedented level of complexity in algorithmic design and software development. In this paper we describe the challenges and design choices involved in parallelization of Bayesian Optimization Algorithm (BOA) to solve complex combinatorial optimization problems over nVidia commodity graphics hardware using Compute Unified Device Architecture (CUDA). BOA is a well-known multivariate Estimation of Distribution Algorithm (EDA) that incorporates methods for learning Bayesian Network (BN). It then uses BN to sample new promising solutions. Our implementation is fully compatible with modern commodity GPUs and therefore we call it gBOA (BOA on GPU). In the results section, we show several numerical tests and performance measurements obtained by running gBOA over an nVidia Tesla C1060 GPU. We show that in the best case we can obtain a speedup of up to 13x.

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# Optimization of Machining Parameters Using Estimation of Distribution Algorithms

Xie, Shu-tong Guo, Yin-biao Huang, Hai-bin Lin, Jing

In computer numerical control (CNC) machining problems, it is important to reduce the production cost To deal with the nonlinear optimization problem of machining parameters which aims to minimize the unit production cost (UC) in multi-pass turning operations, two estimation of distribution algorithms (EDAs) incorporated with gene repair method are proposed to search the optimal solution for machining parameters Computer simulation results show that the proposed algorithms are efficient in searching the optimal machining parameters, which significantly reduce the unit production cost

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# Estimation of Distribution Algorithm Based on Archimedean Copulas

Wang, Li-Fang Zeng, Jian-Chao Hong, Yi

Both Estimation of Distribution Algorithms (EDAs) and Copula Theory are hot topics in different research domains. The key of EDAs is modeling and sampling the probability distribution function which need much time in the available algorithms. Moreover, the modeled probability distribution function can not reflect the correct relationship between variables of the optimization target. Copula Theory provides a correlation between univariable marginal distribution functions and the joint probability distribution function. Therefore, Copula Theory could be used in EDAs. Because Archimedean copulas possess many nice properties, an EDA based on Archimedean copulas is presented in this paper. The experimental results show the effectiveness of the proposed algorithm.

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# Hybrid EDA-based Optimal Attitude Control for a Spacecraft in a Class of Control Task

Luo, Xiong Sun, Zengqi Zhang, Xiang Hu, Laihong Wang, Chao

In the practical situation, if failure of one of the actuators occurs, there exists the attitude control task of a rigid spacecraft using only two control torques supplied by momentum wheel actuators. Here, this class of control task for a rigid spacecraft is discussed. This nonlinear control problem can be converted to the nonholonomic motion planning optimization problem of a drift-free system. In order to improve the search efficiency of current optimization algorithms, the hybrid estimation of distribution algorithm (EDA) is presented by combing the idea of differential evolution strategy (DES). Then, the optimal attitude control task for the spacecraft using two momentum wheel actuators is achieved. By comparing the proposed algorithm with existing genetic algorithm and evolutionary programming, the simulation results show the accuracy and efficiency of hybrid EDA.

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# SGMIT: Using Selfish Gene Theory to Construct Mutual Information Trees for Optimization

Wang, Feng Lin, Zhiyi Yang, Cheng Li, Yuanxiang

In this paper, a new approach named SGMIT in the field of Estimation of Distribution Algorithm (EDA) is proposed. While the current EDAs require much time in the statistical learning process as the relationships among the variables are too complicated, the Selfish Gene Theory (SG) is deployed in this approach and a Mutual Information Tree (MIT) model with an incremental learning and resample scheme is also set to optimize the probability distribution of the virtual population. Experimental results on several benchmark problems demonstrate that, compared with BMDA, COMIT and MIMIC, SGMIT often performs better in convergent reliability, convergent velocity, and convergent process.

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# 3D Vehicle Location Based on Improved Hausdorff Distance and Distributed Estimation Algorithm

Chen, Ying Ji, Zhicheng Hua, Chunjian

3D model is used for vision based vehicle location. An improved Hausdorff distance based on edge-strength is proposed to evaluate the similarity between 3D model projection and image feature, and to establish location optimization function In order to avoid local minimum during optimization, estimation of distribution algorithm concerning related multi-variables is used. The relationship between matching parameters are described with a probability model, and the distribution of parameter evolves towards the direction of dominant character through probability model learning and the corresponding operation, which is proposed to solve the problem of overmany iteration and slow constringency velocity. The experiments show that the optimal matching parameters between 3D model and 2D image feature can be found accurately and efficiently, and the algorithm outperforms other approaches in both accuracy and rapidity.

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# Using Copulas in Estimation of Distribution Algorithms

Salinas-Gutierrez, Rogelio Hernandez-Aguirre, Arturo Villa-Diharce, Enrique R.

A new way of modeling probabilistic dependencies in Estimation of Distribution Algorithm (EDAs) is presented. By means of copulas it is possible to separate the structure of dependence from marginal distributions in a joint distribution. The use of copulas as a mechanism for modeling joint; distributions and its application to EDAs is illustrated on several benchmark examples.

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# Hybridization of Evolutionary Mechanisms for Feature Subset Selection in Unsupervised Learning

Torres, Dolores Ponce-de-Leon, Eunice Torres, Aurora Ochoa, Alberto Diaz, Elva

Feature subset selection for unsupervised learning, is a very important topic in artificial intelligence because it is the base for saving computational resources. In this implementation we use a typical testor's methodology in order to incorporate an importance index for each variable. This paper presents the general framework and the way two hybridized meta-heuristics work in this NP-complete problem. The evolutionary mechanisms are based on the Univariate Marginal Distribution Algorithm (UMDA) and the Genetic Algorithm (GA). GA and UMDA Estimation of Distribution Algorithm (EDA) use a very useful rapid operator implemented for finding typical testors on a very large dataset and also, both algorithms, have a local search mechanism for improving time and fitness. Experiments show that EDA is faster than GA because it has a better exploitation performance; nevertheless. GA' solutions are more consistent.

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# Hybrid Estimation of Distribution Algorithm for permutation flowshop scheduling problem with sequence dependent family setup times

Eddaly, Mansour Jarboui, Bassem Bouabda, Radhouan Rebai, Abdelwaheb

This paper addresses to the scheduling in manufacturing cell environment with sequence dependent family setup times in a flow shop with respect to the makespan criterion. Since this is a NP-hard problem, we present an estimation of distribution algorithm as an evolutionary algorithm for solving it. In order to improve the quality of solution of our algorithm, we propose a hybridization with an iterated local search algorithm. The computational experiments show that our algorithm is better than the evolutionary algorithms proposed in the literature. Moreover, it seems able to provide good results in short computational time.

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# A Self-adaptive Mixed Distribution Based Uni-variate Estimation of Distribution Algorithm for Large Scale Global Optimization

Wang, Yu Li, Bin

Large scale global optimization (LSGO), which is highly needed for many scientific and engineering applications, is a very important and very difficult task in optimization domain. Various algorithms have been proposed to tackle this challenging problem, but the use of estimation of distribution algorithms (EDAs) to it is rare. This chapter aims at investigating the behavior and performances of univariate EDAs mixed with different kernel probability densities via fitness landscape analysis. Based on the analysis, a self-adaptive uni-variate EDA with mixed kernels (MUEDA) is proposed. To assess the effectiveness and efficiency of MUEDA, function optimization tasks with dimension scaling from 30 to 1500 are adopted. Compared to the recently published LSGO algorithms, MUEDA shows excellent convergence speed, final solution quality and dimensional scalability.

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# Motif Discovery Using Evolutionary Algorithms

Shao, Linlin Chen, Yuehui Abraham, Ajith

The bacterial foraging optimization (BFO) algorithm is a nature and biologically inspired computing method. We propose an alternative solution integrating bacterial foraging optimization algorithm and tabu search (TS) algorithm namely TS-BFO. We modify the original BFO via established a self-control multi-length chemotactic step mechanism, and introduce rao metric. We utilize it to solve motif discovery problem and compare the experimental result with existing famous DE/EDA algorithm which combines global information extracted by estimation of distribution algorithm (EDA) with differential information obtained by Differential evolution (DE) to search promising solutions. The experiments on real data set selected from TRANSFAC and SCPD database have predicted meaningful motif which demonstrated that TS-BFO and DE/EDA are promising approaches for finding motif and enrich the technique of motif discovery.

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# A Novel Fuzzy Histogram based Estimation of Distribution Algorithm for Global Numerical Optimization

Liu, Weili Zhong, Jing-hui Wu, Wei-gang Xiao, Jing Zhang, Jun

Applying Estimation of Distribution Algorithms (EDAs) to solve continuous problems is a significant and challenging task in the field of evolutionary computation. So far, various continuous EDAs have been developed based on different probability models. Initially, the EDAs based on a single Gaussian probability model are widely used but they have trouble in solving multimodal problems. Later EDAs based on a mixture model and on a clustering technique are then introduced to conquer such drawback. However, they are either time consuming or need prior knowledge of the problems. Recently, the histogram has begun to be used in continuous EDAs, but the histogram based EDAs (HEDAs) usually need too much time and space to gain a highly accurate solution. On the basis of pioneering contributions, this paper proposes a fuzzy histogram based EDA (FHEDA) for continuous optimization. In the FHEDA, the estimated range of the fuzzy histogram is adjusted adaptively by the current promising solutions, which leads the algorithm to search good solutions efficiently. A mutation mechanism is also introduced in the sampling operation to avoid being trapped in local optima. The performance of the proposed FHEDA is evaluated by testing seven benchmark functions with different characteristics. Two Gaussian based EDAs and the sur-shr-HEDA are studied for comparison. The results show that among all experimental algorithms, the FHEDA can give comparatively satisfying performance on unimodal and multimodal functions.

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# On the Computational Properties of the Multi-Objective Neural Estimation of Distribution Algorithm

Marti, Luis Garcia, Jesus Berlanga, Antonio Molina, Jose M.

This paper explores the behavior of the multi-objective neural EDA (MONEDA) in terms of its computational requirements it demands and assesses how it scales when dealing with multi-objective optimization problems with relatively large amounts of objectives. In order to properly comprehend these matters other MOEDAs and MOEAs are included in the analysis. The experiments performed tested the ability of each approach to scalably solve many-objective optimization problems. The fundamental result obtained is that MONEDA is not only yields similar or better solutions when compared with other approaches but also does it with at a lower computational cost.

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# When Is an Estimation of Distribution Algorithm Better than an Evolutionary Algorithm?

Chen, Tianshi Lehre, Per Kristian Tang, Ke Yao, Xin

Despite the wide-spread popularity of estimation of distribution algorithms (EDAs), there has been no theoretical proof that there exist optimisation problems where EDAs perform significantly better than traditional evolutionary algorithms. Here, it is proved rigorously that on a problem called SUBSTRING, a simple EDA called univariate marginal distribution algorithm (UMDA) is efficient, whereas the (1+1) EA is highly inefficient. Such studies are essential in gaining insight into fundamental research issues, i.e., what problem characteristics make an EDA or EA efficient, under what conditions an EDA is expected to outperform an EA, and what key factors are in an EDA that make it efficient or inefficient.

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# Estimation of Distribution Algorithm Based on Copula Theory

Wang, Li-Fang Zeng, Jian-Chao Hong, Yi

Estimation of Distribution Algorithm (EDA) is a novel evolutionary computation, which mainly depends on learning and sampling mechanisms to manipulate the evolutionary search, and has been proved a potential technique for complex problems. However, EDA generally spend too much time on the learning about the probability distribution of the promising individuals. The paper propose an improved EDA based on copula theory (copula-EDA) to enhance the learning efficiency, which models and samples the joint probability function by selecting a proper copula and learning the marginal probability distributions of the promising population. The simulating results prove the approach is easy to implement and is validated on several problems.'

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# Structure Learning and Optimisation in a Markov-network based Estimation of Distribution Algorithm

Brownlee, Alexander E. I. McCall, John A. W. Shakya, Siddartha K. Zhang, Qingfu

Structure learning is a crucial component of a multivariate Estimation of Distribution algorithm. It is the part which determines the interactions between variables in the probabilistic model, based on analysis of the fitness function or a population. In this paper we take three different approaches to structure learning in an EDA based on Markov networks and use measures from the information retrieval community (precision, recall and the F-measure) to assess the quality of the structures learned. We then observe the impact that structure has on the fitness modelling and optimisation capabilities of the resulting model, concluding that these results should be relevant to research in both structure learning and fitness modelling.

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# Hybrid Multiobjective Estimation of Distribution Algorithm by Local Linear Embedding and an Immune Inspired Algorithm

Yang, Dongdong Jiao, Licheng Gong, Maoguo Feng, Hongxiao

A novel hybrid multiobjective estimation of distribution algorithm is proposed in this study. It combines an estimation of distribution algorithm based on local linear embedding and an immune inspired algorithm. Pareto set to the continuous multiobjective optimization problems, in the decision space, is a piecewise continuous (m-1)-dimensional manifold, where m is the number of objectives. By this regularity, a local linear embedding based manifold algorithm is introduced to build the distribution model of promising solutions. Besides, for enhancing local search ability of the EDA, an immune inspired sparse individual clone algorithm (SICA) is introduced and combined with the EDA. The novel hybrid multiobjective algorithm, named HMEDA, is proposed accordingly. Compared with three other state-of-the-art multiobjective algorithms, this hybrid algorithm achieves comparable results in terms of convergence and diversity. Besides, the tradeoff proportions of EDA to SICA in HMEDA are studied. Finally, the scalabitity to the number of decision variables of HMEDA is investigated too.

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# Evolutionary Algorithm using Kernel Density Estimation Model in Continuous Domain

Luo, Na Qian, Feng

Estimation of Distribution Algorithm (EDA) is a kind of evolutionary algorithm which updates and samples from probabilistic model in evolutionary course. The key of EDA is the construction of probability model suitable for real distribution. Gaussian distribution is widely used in EDAs but the assumption of normality is not realistic for many real-life problems. In this paper, a new EDA using kernel density estimation (KEDA) is introduced. Adaptive change strategy of kernel width is presented and selection scheme, sampling method are also given cooperated with KEDA. The results of 5 benchmark functions show that results of KEDA outperform PBILC, UMDA(C), EDA(G), H-EDA.

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# Bayesian Optimization Algorithm for the Non-unique Oligonucleotide Probe Selection Problem

Ghoraie, Laleh Soltan Gras, Robin Wang, Lili Ngom, Alioune

DNA microarrays are used in order to recognize the presence or absence of different biological components (targets) in a sample. Therefore, the design of the microarrays which includes selecting short Oligonucleotide sequences (probes) to be affixed on the surface of the microarray becomes a major issue. This paper focuses on the problem of computing the minimal set of probes which is able to identify each target of a sample, referred to as Non-unique Oligonucleotide Probe Selection. We present the application of an Estimation of Distribution Algorithm (EDA) named Bayesian Optimization Algorithm (BOA) to this problem, for the first time. The presented approach considers integration of BOA and state-of-the-art, heuristics introduced for the non-unique probe selection problem. This approach provides results that compare Favorably with the state-of-the-art methods. It is also able to provide biologists with more information about the dependencies between the probe sequences of each dataset.

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# Advanced design and optimization of single mode photonic crystal fibers

Pourmahayabadi, M. Nejad, S. Mohammad

This paper proposes a combination of differential evolution (DE) and estimation of distribution algorithm (EDA) to design photonic crystal fiber structures with desired properties over the C communication band. In order to determine the properties of PCFs such as dispersion, dispersion slope and loss, an artificial intelligence method, the Nero-Fuzzy system, is applied. In addition, a special cost function which simultaneously includes the confinement loss, dispersion and its slope is used in the proposed design approach. The results revealed that the proposed method is a powerful tool for solving this optimization problem. The optimized PCF exhibits an ultra low confinement loss and low dispersion at 1.55 mu m wavelength with a nearly zero dispersion slope over the C communication band.

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# Design of ultra-low and ultra-flattened dispersion single mode photonic crystal fiber by DE/EDA algorithm

Pourmahayabadi, M. Nejad, S. Mohammad

This paper proposes a combination of differential evolution (DE) and estimation of distribution algorithm (EDA) to design photonic crystal fiber structures with desired properties over the C communication band. In order to determine the effective index of propagation of the mode and then, the other properties of structure, a finite difference frequency domain (FDFD) solver is applied. The results revealed that the proposed method is a powerful tool for solving this optimization problem. The optimized PCF exhibits a dispersion of 0.22 ps nm-1 km-1 at 1.55 mu m wavelength with a variance of +/- 0.4 ps nm-1 km-1 over the C communication band and a nearly zero dispersion slope.

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# Training Artificial Neural Networks Via Estimation of Distribution Algorithm

Liao, Weifang Jiang, Yong Song, Changhui

Apply Estimation of Distribution Algorithm (EDA) to optimize the weights of neural networks, solving the problem of traditional BP algorithm convergence rate is too slow and easy to fall into the local minimum solutions. And use this method to design neural network classifier and obtain very good results.

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# PDE-PEDA: A New Pareto-Based Multi-objective Optimization Algorithm

Wang, Xuesong Hao, Minglin Cheng, Yuhu Lei, Ruhai

Differential evolution (DE) algorithm puts emphasis particularly on imitating the microscopic behavior of individuals, while estimation of distribution algorithm (EDA) tries to estimate the probabilistic distribution of the entire population. DE and EDA can be extended to multi-objective optimization problems by using a Pareto-based approach, called Pareto DE (PDE) and Pareto EDA (PEDA) respectively. In this study, we describe a novel combination of PDE and PEDA (PDE-PEDA) for multi-objective optimization problems by taking advantage of the global searching ability of PEDA and the local optimizing ability of PDE, which can, effectively, maintain the balance between exploration and exploitation. The basic idea is that the offspring population of PDE-PEDA is composed of two parts, one part of the trial solution generated originates from PDE and the other part is sampled in the search space from the constructed probabilistic distribution model of PEDA. A scaling factor Pr used to balance contributions of PDE and PEDA can be adjusted in an on-line manner using a simulated annealing method. At an early evolutionary stage, a larger Pr should be adopted to ensure PEDA is used more frequently, whereas at later stage, a smaller Pr should be adopted to ensure that offspring is generated more often using PDE. The hybrid algorithm is evaluated on a set of benchmark problems and the experimental results show that PDE-PEDA outperforms the NSGA-II and PDE algorithms.

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# Estimation of Distribution Algorithm for Scheduling in Uplink Multiuser Wireless Communication System

Naeem, M. Lee, D. C.

In this paper, we present a real-time low-complexity user scheduling scheme for uplink multiuser multiple input multiple output (MIMO) wireless communication systems. We apply Estimation of Distribution Algorithm (EDA) for user scheduling problem. The computational complexity of exhaustive search for user scheduling problem grows exponentially with the number of users. The proposed EDA has low computational complexity and can find a near-optimum solution in real time. In addition to applying the general EDA to user scheduling, we also present a specific improvement to EDA, which increases the likelihood of getting the optimum solution by generating cyclic shifted initial population.

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