# Sensibility of Linkage Information and Effectiveness of Estimated Distributions

Chuang, Chung-Yao Chen, Ying-ping

The probabilistic model building performed by estimation of distribution algorithms (EDAs) enables these methods to use advanced techniques of statistics and machine learning for automatic discovery of problem structures. However, in some situations, it may not be possible to completely and accurately identify the whole problem structure by probabilistic modeling due to certain inherent properties of the given problem. In this work, we illustrate one possible cause of such situations with problems consisting of structures with unequal fitness contributions. Based on the illustrative example, we introduce a notion that the estimated probabilistic models should be inspected to reveal the effective search directions and further propose a general approach which utilizes a reserved set of solutions to examine the built model for likely inaccurate fragments. Furthermore, the proposed approach is implemented on the extended compact genetic algorithm (ECGA) and experiments are performed on several sets of additively separable problems with different scaling setups. The results indicate that the proposed method can significantly assist ECGA to handle problems comprising structures of disparate fitness contributions and therefore may potentially help EDAs in general to overcome those situations in which the entire problem structure cannot be recognized properly due to the temporal delay of emergence of some promising partial solutions.

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# ON THE PROBABILISTIC OPTIMIZATION OF SPIKING NEURAL NETWORKS

Schliebs, Stefan Kasabov, Nikola Defoin-Platel, Michael

The construction of a Spiking Neural Network (SNN), i.e., the choice of an appropriate topology and the configuration of its internal parameters, represents a great challenge for SNN based applications. Evolutionary Algorithms (EAs) offer an elegant solution for these challenges and methods capable of exploring both types of search spaces simultaneously appear to be the most promising ones. A variety of such heterogeneous optimization algorithms have emerged recently, in particular in the field of probabilistic optimization. In this paper, a literature review on heterogeneous optimization algorithms is presented and an example of probabilistic optimization of SNN is discussed in detail. The paper provides an experimental analysis of a novel Heterogeneous Multi-Model Estimation of Distribution Algorithm (hMM-EDA). First, practical guidelines for configuring the method are derived and then the performance of hMM-EDA is compared to state-of-the-art optimization algorithms. Results show hMM-EDA as a light-weight, fast and reliable optimization method that requires the configuration of only very few parameters. Its performance on a synthetic heterogeneous benchmark problem is highly competitive and suggests its suitability for the optimization of SNN.

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# Estimation of Distribution Algorithm Incorporating Switching

Tsuchie, Kenji Hanada, Yoshiko Miyoshi, Seiji

We propose an estimation of distribution algorithm in corporating switching The algorithm enables switching from the standard estimation of distribution algorithm (EDA) to the genetic algorithm (GA) or vice versa on the basis of switching criteria The algorithm shows better performance than GA and EDA in deceptive problems.

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# Multi-marker tagging single nucleotide polymorphism selection using estimation of distribution algorithms

Santana, Roberto Mendiburu, Alexander Zaitlen, Noah Eskin, Eleazar Lozano, Jose A.

Objectives This paper presents an optimization algorithm for the automatic selection of a minimal subset of tagging single nucleotide polymorphisms (SNPs)

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# Two-level evolutionary approach to the survivable mesh-based transport network topological design

Sun, J. Zhang, Q. Li, J.

The complete topology design problem of survivable mesh-based transport networks is to address simultaneously design of network topology, working path routing, and spare capacity allocation based on span-restoration. Each constituent problem in the complete design problem could be formulated as an Integer Programming (IP) and is proved to be NP-hard. Due to a large amount of decision variables and constraints involved in the IP formulation, to solve the problem directly by exact algorithms (e. g. branch-and-bound) would be impractical if not impossible. In this paper, we present a two-level evolutionary approach to address the complete topology design problem. In the low-level, two parameterized greedy heuristics are developed to jointly construct feasible solutions (i.e., closed graph topologies satisfying all the mesh-based network survivable constraints) of the complete problem. Unlike existing "zoom-in"-based heuristics in which subsets of the constraints are considered, the proposed heuristics take all constraints into account. An estimation of distribution algorithm works on the top of the heuristics to tune the control parameters. As a result, optimal solution to the considered problem is more likely to be constructed from the heuristics with the optimal control parameters. The proposed algorithm is evaluated experimentally in comparison with the latest heuristics based on the IP software CPLEX, and the "zoom-in"-based approach on 28 test networks problems. The experimental results demonstrate that the proposed algorithm is more effective in finding high-quality topologies than the IP-based heuristic algorithm in 21 out of 28 test instances with much less computational costs, and performs significantly better than the "zoom-in"-based approach in 19 instances with the same computational costs.

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# Optimal decoding and minimal length for the non-unique oligonucleotide probe selection problem

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

One of the applications of DNA microarrays is recognizing the presence or absence of different biological components (targets) in a sample. Hence, the quality of the microarrays design which includes selecting short Oligonucleotide sequences (probes) to be affixed on the surface of the microarray becomes a major issue. A good design is the one that contains the minimum possible number of probes while having an acceptable ability in identifying the targets existing in the sample. 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 proposed approach considers integration of BOA and one simple heuristic introduced for the non-unique probe selection problem. The results provided by this approach compare favorably with the state-of-the-art methods in the single target case. While most of the recent research works on this problem has been focusing on the single target case only, we present the application of our method in integration with decoding approach in a multiobjective optimization framework for solving the problem in the case of multiple targets. Crown Copyright (C) 2010 Published by Elsevier B.V. All rights reserved.

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# Discrete Hopfield network combined with estimation of distribution for unconstrained binary quadratic programming problem

Wang, Jiahai

Unconstrained binary quadratic programming problem (UBQP) consists in maximizing a quadratic 0-1 function. It is a well known NP-hard problem and is a unified model for a variety of combinatorial optimization problems. This paper presents a discrete Hopfield neural network (DHNN) combined with estimation of distribution algorithm (EDA) for the UBQP. The idea of EDA is combined with the DHNN in order to overcome the local minima problem of the network. Once the network is trapped in local minima, the perturbation based on EDA can generate a new starting point for the DHNN for further search, which is in a promising area characterized by a probability model. Thus, the proposed algorithm, named DHNN-EDA, can escape from local minima and further search better results. The DHNN-EDA is tested on a large number of benchmark problems with size up to 7000 variables. Simulation results on the UBQP show that the DHNN-EDA is better than the other improved DHNN algorithms such as multi-start DHNN and DHNN with random flips, and is better than or competitive with metaheuristic algorithms such as simulated annealing, tabu search, scatter search and memetic algorithm. (C) 2010 Elsevier Ltd. All rights reserved.

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# A Hybrid EDA for Protein Folding Based on HP Model

Chen, Benhui Hu, Jinglu

Protein structure prediction (PSP) is one of the most important problems in computational biology. This paper proposes a novel hybrid estimation of distribution algorithm (EDA) to solve the PSP problem on HP model. First, a composite fitness function containing the information cif folding structure core (I-I-core) is introduced to replace the traditional fitness function of HP model. The proposed fitness function is expected to select better individuals for the probabilistic model of EDA. Second, local search with guided operators is utilized to refine the found solutions for improving the efficiency of EDA. Third, an improved backtracking-based repairing method is proposed to repair invalid individuals sampled by the probabilistic model of EDA. It can significantly reduce the number of backtracking searching operation and the computational cost for a long-sequence protein. Experimental results demonstrate that the proposed method outperform the basic EDA method. At the same time, it is very competitive with other existing algorithms for the PSP problem on lattice HP models. (C) 2010 Institute of Electrical Engineers of Japan. Published by John Wiley &amp; Sons, Inc.

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# Enabling the Extended Compact Genetic Algorithm for Real-Parameter Optimization by Using Adaptive Discretization

Chen, Ying-ping Chen, Chao-Hong

An adaptive discretization method, called split-on-demand (SoD), enables estimation of distribution algorithms (EDAs) for discrete variables to solve continuous optimization problems. SoD randomly splits a continuous interval if the number of search points within the interval exceeds a threshold, which is decreased at every iteration. After the split operation, the nonempty intervals are assigned integer codes, and the search points are discretized accordingly. As an example of using SoD with EDAs, the integration of SoD and the extended compact genetic algorithm (ECGA) is presented and numerically examined. In this integration, we adopt a local search mechanism as an optional component of our back end optimization engine. As a result, the proposed framework can be considered as a memetic algorithm, and SoD can potentially be applied to other memetic algorithms. The numerical experiments consist of two parts: (1) a set of benchmark functions on which ECGA with SoD and ECGA with two well-known discretization methods: the fixed-height histogram (FHH) and the fixed-width histogram (FWH) are compared; (2) a real-world application, the economic dispatch problem, on which ECGA with SoD is compared to other methods. The experimental results indicate that SoD is a better discretization method to work with ECGA. Moreover, ECGA with SoD works quite well on the economic dispatch problem and delivers solutions better than the best known results obtained by other methods in existence.

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# Hybrid sampling on mutual information entropy-based clustering ensembles for optimizations

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

In this paper, we focus on the design of bivariate EDAs for discrete optimization problems and propose a new approach named HSMIEC. While the current EDAs require much time in the statistical learning process as the relationships among the variables are too complicated, we employ the Selfish gene theory (SG) in this approach, as well as a Mutual Information and Entropy based Cluster (MIEC) model is also set to optimize the probability distribution of the virtual population. This model uses a hybrid sampling method by considering both the clustering accuracy and clustering diversity and an incremental learning and resample scheme is also set to optimize the parameters of the correlations of the variables. Compared with several benchmark problems, our experimental results demonstrate that HSMIEC often performs better than some other EDAs, such as BMDA, COMIT, MIMIC and ECGA. (C) 2009 Elsevier B.V. All rights reserved.

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# Optimization of depleted uranium bundle loading in fresh core of Indian PHWR by evolutionary algorithm

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

This paper is concerned with the Indian design of a 220 MWe pressurized heavy water reactor (PHWR) having natural uranium (NU) fuel and heavy water as moderator and coolant. At the beginning of life, it is necessary to flatten the power by loading some depleted uranium (DU) bundles to achieve a nearly full power operation. The determination of best possible locations of DU bundles, which maximize fuel economy as well as safety, is a large-sized combinatorial optimization problem with constraints. In the past, 384 DU bundles have been loaded in locations determined by manual intuition in an Indian PHWR and maximum permissible power of 93% full power (FP) was obtained. In the present paper, a modern evolutionary algorithm called estimation of distribution algorithm (EDA) is used to improve upon this distribution. Optimum distributions of DU bundles which maximize K(eff) and give 100% FP without violating safety parameters such as maximum permissible bundle power, channel power, channel outlet temperature and permitted reactivity worths of shut-down systems are obtained. Another aspect studied in this paper is to find out how far one can increase the number of DU bundles loaded in the core. This will minimize the NU bundles requirement, extract more power from DU bundles and thus provide better fuel utilization. The idea is to conserve NU bundles. The optimum distribution of DU bundles has been obtained for the total number of DU bundles ranging from a few hundreds to a few thousands. It is found that, depending on various conditions, about 60-80% of the core can be loaded with DU bundles leading to a substantial saving in NU bundles. Some variation in the implementation of EDA to generate loading pattern of PHWR reactor core is also studied. (C) 2009 Elsevier Ltd. All rights reserved.

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# A Novel Memetic Algorithm for Constrained Optimization

Sun, Jianyong Garibaldi, Jonathan M.

In this paper, we present a memetic algorithm with novel local optimizer hybridization strategy for constrained optimization. The developed MA consists of multiple cycles. In each cycle, an estimation of distribution algorithm (EDA) with an adaptive univariate probability model is applied to search for promising search regions. A classical local optimizer, called DONLP2, is applied to improve the best solution found by the EDA to a high quality solution. New cycles are employed when the computational budget has not been reached. The new cycles are expected to learn from the search history to make the further search efficient and to enable escape from local optima. The developed algorithm is experimentally compared with epsilon-DE, which was the winner of the 2006 IEEE Congress on Evolutionary Computation (CEC'06) competition on constrained optimization. The results favour our algorithm against the best-known algorithm in terms of the number of fitness evaluations used to reach the global optimum.

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# Restricted Boltzmann Machine Based Algorithm for Multi-objective Optimization

Tang, Huajin Shim, Vui Ann Tan, Kay Chen Chia, Jun Yong

Restricted Boltzmann machine is an energy-based stochastic neural network with unsupervised learning. This network consists of a layer of hidden unit and visible unit in an undirected generative network. In this paper, restricted Boltzmann machine is modeled as estimation of distribution algorithm in the context of multi-objective optimization. The probabilities of the joint configuration over the visible and hidden units in the network are trained until the distribution over the global state reach a certain degree of thermal equilibrium. Subsequently, the probabilistic model is constructed using the energy function of the network. Moreover, the proposed algorithm incorporates clustering in phenotype space and other canonical operators. The effects on the stability of the trained network and clustering in optimization are rigorously examined. Experimental investigations are conducted to analyze the performance of the algorithm in scalable problems with high numbers of objective functions and decision variables.

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# The Parameter Estimation of Clayton Copula Estimation of Distribution Algorithm

Wang, Ying-Cong Wang, Li-Fang Zeng, Jian-Chao

Copula theory is used in copula Estimation of Distribution Algorithm(cEDA). According to the copula theory, it enable us to separate joint probability distribution function into the product of univariate margins and a copula which represents the dependency structure of random variables. Clayton cEDA uses Clayton copula and empirical distribution to describe the distribution model of the selected population. But different parameters of Copula represent different dependency structures, and the new generation is influenced by the estimated distribution model. In order to estimate the dependency structure more exactly and to guide correctly the evolutionary direction of new generation, maximum likelihood estimation (MLE) is used to estimate the parameter of Clayton cEDA. The experimental results show the effectiveness of the algorithm.

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# An Estimation of Distribution Algorithm using the LZW Compression Algorithm

Watchanupaporn, Orawan Suwannik, Worasait

This paper proposes a new evolutionary algorithm called LZWCGA. LZWCGA is an algorithm that combines the LZW compressed chromosome encoding and compact genetic algorithm (cGA). The advantage of LZW encoding is to reduce the search space thus speed up the evolutionary search. cGA is one of Estimation of Distribution Algorithms. Its advantage is compact representation of the whole binary-string genetic algorithm population.

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# Comparison of Cauchy EDA and G3PCX Algorithms on the BBOB Noiseless Testbed

Posik, Petr

Estimation-of-distribution algorithm equipped with Cauchy sampling distribution is compared with the generalized generation gap algorithm with parent centric crossover. Both algorithms were already presented at the 2009 black-box optimization benchmarking workshop where they often showed similar performance. This paper compares them in more detail and adds to the understanding of their key features and differences.

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# Comparison of Cauchy EDA and Rosenbrock's Algorithms on the BBOB Noiseless Testbed

Posik, Petr

Estimation-of-distribution algorithm equipped with Cauchy distribution (Cauchy EDA) is compared with Rosenbrock's local search algorithm. Both algorithms were already presented at the 2009 black-box optimization benchmarking workshop where Cauchy EDA usually ranked better than Rosenbrock's algorithm. This paper compares them in more detail and adds to the understanding of their key differences.

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# Comparison of Cauchy EDA and pPOEMS algorithms on the BBOB Noiseless Testbed

Posik, Petr Kubalik, Jiri

Estimation-of-distribution algorithm using Cauchy sampling distribution is compared with the iterative prototype optimization algorithm with evolved improvement steps. While Cauchy EDA is better on unimodal functions, iterative prototype optimization is more suitable for multimodal functions. This paper compares the results for both algorithms in more detail and adds to the understanding of their key features and differences.

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# Comparison of Cauchy EDA and BIPOP-CMA-ES Algorithms on the BBOB Noiseless Testbed

Posik, Petr

Estimation-of-distribution algorithm using Cauchy sampling distribution is compared with the bi-population CMA evolutionary strategy which was one of the best contenders in the black-box optimization benchmarking workshop in 2009. The results clearly indicate that the CMA evolutionary strategy is in all respects a better optimization algorithm than the Cauchy estimation-of-distribution algorithm. This paper compares both algorithms in more detail and adds to the understanding of their key features and differences.

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# Stochastic Local Search in Continuous Domains Questions to be Answered When Designing A Novel Algorithm

Posik, Petr

Several population-based methods (with origins in the world of evolutionary strategies and estimation-of-distribution algorithms) for black-box optimization in continuous domains are surveyed in this article. The similarities and differences among them are emphasized and it is shown that they all can be described in a common framework of stochastic local search-a class of methods previously defined mainly for combinatorial problems. Based on the lessons learned from the surveyed algorithms, a set of algorithm features (or, questions to be answered) is extracted. An algorithm designer can take advantage of these features and by deciding on each of them, she can construct a novel algorithm. A few examples in this direction are shown.

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# Co-evolving Best Response Strategies for P-S-Optimizing Negotiation using Evolutionary Algorithms

Gwak, Jeonghwan Sim, Kwang Mong

This paper presents the comparative study of two different evolutionary approaches, a genetic algorithm (GA) and an estimation of distribution algorithm (EDA), in co-evolving negotiation strategies with different preference criteria such as optimizing price and optimizing negotiation speed. Empirical studies demonstrate that both GA and EDA are successful in finding good solutions in price optimizing and speed optimizing negotiation, respectively. However, both are not successful in price and speed concurrent optimizing (P-S-Optimizing) negotiation. From these results, finally, this paper suggests a novel method to find best response strategies for P-S-Optimizing negotiation.

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# A Learning Strategy for Multi-robot Based on Probabilistic Evolutionary Algorithm

Fan, Jiancong Liang, Yongquan Ruan, Jiuhong

Estimation of distribution algorithm (EDA) is a new evolutionary computation method based on probabilistic theory. EDA can select optimal individuals through estimating probability distribution function of a population. The capture problem among multi software robots can be solved by EDA. The capture problem involves that some pursuers pursue several evaders through part of trajectory. The trajectory was produced by the evaders during their two-dimensional random mobility. The pursuers estimate the evaders' mobility functions and adjust their pursuit models to capture the evaders as fast as possible. The probabilistic evolutionary courses of multi-robot experiencing some competitions are analyzed in performances. The analysis shows that capture problem of multi-robot solved by EDA is better than other methods in several aspects.

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# Multi-Objective Evolutionary of Distribution Algorithm Using Kernel Density Estimation Model

Luo, Na Qian, Feng

Estimation of Distribution Algorithm (EDA) is a kind of new evolutionary algorithm which updates and samples from probabilistic model in evolutionary computation. Recently it is used to solve multi-objective problems. The key is how to construct probability model suitable for real distribution and how to keep diversity of solutions. In this paper a new multi-objective evolutionary of distribution algorithm using kernel density estimation model is presented. It used kernel density estimation method to obtain probability density of samples and generate new population with stochastic universal sampling method. In order to get pareto front of multi-objective problems, fitness sharing method is used. 5 bi-objective test problems are selected to test the performance of the new algorithm. The results show that multi-objective evolutionary of distribution algorithm using kernel density estimation model has better suitable performance for test problems comparing with non-dominated sorting genetic algorithm II, multi-objective particle swarm optimization and multi-objective estimation of distribution algorithm.

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# Protein Structure Prediction Based on HP Model Using an Improved Hybrid EDA

Chen, Benhui Hu, Jinglu

Protein structure prediction (PSP) is one of the most important problems in computational biology. This chapter introduces a novel hybrid Estimation of Distribution Algorithm (EDA) to solve the PSP problem on HP model. Firstly, a composite fitness function containing the information of folding structure core (H-Core) is introduced to replace the traditional fitness function of HP model. The new fitness function is expected to select better individuals for probabilistic model of EDA. Secondly, local search with guided operators is utilized to refine found solutions for improving efficiency of EDA. Thirdly, an improved backtracking-based repairing method is introduced to repair invalid individuals sampled by the probabilistic model of EDA. It can significantly reduce the number of backtracking searching operation and the computational cost for long sequence protein. Experimental results demonstrate that the new method outperforms the basic EDAs method. At the same time, it is very competitive with other existing algorithms for the PSP problem on lattice HP models.

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# Estimation of Distribution Algorithm Based on Copula Theory

Wang, Li-Fang Zeng, Jian-Chao

Estimation of Distribution Algorithms (EDAs) is the hot topic of evolutionary computation currently. EDAs model the selected population using a distribution model, which is latter sampled to generate the population for the next generation. This chapter introduces a new way to estimate the distribution model and sample from it according to copula theory. The multivariate joint is decomposed into the univariate margins and a function called copula. In the EDAs based on copula theory (copula-EDAs), only the margins are estimated, and the next generation is sampled from the copula and the inverse function of the margins. The framework of the copula-EDAs is discussed in the chapter. Two 2-dimensional copula-EDAs and a high-dimensional copula-EDA are described in detail as the examples.

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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, Siddhartha K. Zhang, Qingfu

Linkage learning has been a focus of research interest since the early days of evolutionary computation. There is a strong connection between linkage learning and the concept of structure learning, which is a crucial component of a multivariate Estimation of Distribution Algorithm. Structure learning determines the interactions between variables in the probabilistic model of an EDA, based on analysis of the fitness function or a population. In this chapter we apply 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 present observations and analysis of the impact that structure learning has on optimisation performance and fitness modelling.

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# An estimation of distribution algorithm for resource-constrained project scheduling problem

Fang, Chen Wang, Ling Xu, Ye

An estimation of distribution algorithm (EDA) is proposed to solve resource-constrained project scheduling problem (RCPSP). In the EDA, individual is encoded based on the extended active list, and a probability model of the distribution for each activity in a project and its updating mechanism are proposed. The algorithm determines the initial probability matrix according to an initial set of solutions generated by the regret-based sampling method and priority rule, and decodes the individuals by using serial schedule generation scheme. Meanwhile, a permutation based local search method is incorporated into the algorithm to enhance the exploitation ability so as to further improve the searching quality. Simulation results based on benchmarks and comparisons with some existing algorithms demonstrate the feasibility and effectiveness of our proposed EDA.

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# Probabilistic Based Evolutionary Optimizers in Bi-objective Travelling Salesman Problem

Shim, Vui Ann Tan, Kay Chen Chia, Jun Yong

This paper studies the probabilistic based evolutionary algorithms in dealing with bi-objective travelling salesman problem. Multi-objective restricted Boltzmann machine and univariate marginal distribution algorithm in binary representation are modified into permutation based representation. Each city is represented by an integer number and the probability distributions of the cities are constructed by running the modeling approach. A refinement operator and a local exploitation operator are proposed in this work. The probabilistic based evolutionary optimizers are subsequently combined with genetic based evolutionary optimizer to complement the limitations of both algorithms.

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# MP-EDA: A Robust Estimation of Distribution Algorithm with Multiple Probabilistic Models for Global Continuous Optimization

Zhong, Jing-hui Zhang, Jun Fan, Zhun

Extending Estimation of distribution algorithms (EDAs) to the continuous field is a promising and challenging task. With a single probabilistic model, most existing continuous EDAs usually suffer from the local stagnation or a low convergence speed. This paper presents an enhanced continuous EDA with multiple probabilistic models (MP-EDA). In the MP-EDA, the population is divided into two subpopulations. The one involved by histogram model is used to roughly capture the global optima, whereas the other involved by Gaussian model is aimed at finding highly accurate solutions. During the evolution, a migration operation is periodically carried out to exchange some best individuals of the two subpopulations. Besides, the MP-EDA adaptively adjusts the offspring size of each subpopulation to improve the searching efficiency. The effectiveness of the MP-EDA is investigated by testing ten benchmark functions. Compared with several state-of-the-art evolutionary computations, the proposed algorithm can obtain better results in most test cases.

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# The RM-MEDA Based on Elitist Strategy

Mo, Li Dai, Guangming Zhu, JianKai

The Estimation of Distribution Algorithms(EDAs) is a new paradigm for Evolutionary Computation. This new class of algorithms generalizes Genetic Algorithms(GAs) by replacing the crossover and mutation operaters by learning and sampling the probability distribution of the best individuals of the population at each iteration of the algorithm. In this paper, we review the EDAs for the solution of combinatorial optimization problems and optimization in continuous domains. The paper gives a brief overview of the multiobjective problems(MOP) and estimation of distribution algorithms(EDAs). We introduce a representative algorithm called RMMEDA (Regularity Model Based Multi-objective Estimation of Distribution Algorithm). In order to improve the convergence performance of the algorithm, we improve the traditional RM-MEDA. The improvement we make is using part of the parent population with better performance instead of the entire parent population to establish a more accurate manifold model, and the RM-MEDA based on elitist strategy theory is proposed. Experimental results show that the improved RMMEDA performs better on the convergence metric and the algorithm runtime than the original one.

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# Parameter Evolution for a Particle Swarm Optimization Algorithm

Zhou, Aimin Zhang, Guixu Konstantinidis, Andreas

Setting appropriate parameters of an evolutionary algorithm (EA) is challenging in real world applications. On one hand, the characteristics of a real world problem are usually unknown. On the other hand, in different running stages of an EA, the best parameters may be different. Thus adaptively tuning algorithm parameters online is preferred. In this paper, we propose to use an estimation of distribution algorithm (EDA) to do this for a particle swarm optimization (PSO) algorithm. The major characteristic of our approach is that there are two evolving processes simultaneously: one for tackling the original problem, and the other for optimizing PSO parameters. For the former evolving process, a set of particles are maintained; while for the later, a probability distribution model of the PSO parameters is maintained throughout the run. In the reproduction procedure, the PSO parameters are firstly sampled from the model, and then new particles are generated by the PSO operator. The feedback from the newly generated particles is used to evaluate the PSO parameters and thus to update the probability model. The new approach is applied to a set of test instances and the preliminary results are promising.

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# An Estimation of Distribution Algorithm Based on Clayton Copula and Empirical Margins

Wang, L. F. Wang, Y. C. Zeng, J. C. Hong, Y.

Estimation of Distribution Algorithms (EDAs) are new evolutionary algorithms which based on the estimation and sampling the distribution model of the selected population in each generation. The way of copula used in EDAs is introduced in this paper. The joint distribution of the selected population is separated into the univariate marginal distribution and a function called copula to represent the dependence structure. And the new individuals are obtained by sampling from copula and then calculating the inverse of the univariate marginal distribution function. The empirical distribution and Clayton copula are used to implement the proposed copula Estimation of Distribution Algorithm (copula EDA). The experimental results show that the proposed algorithm is equivalent to some conventional continuous EDAs in performance.

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# An Investigation on Sampling Technique for Multi-objective Restricted Boltzmann Machine

Shim, Vui Ann Tan, Kay Chen Chia, Jun Yong

Estimation of distribution algorithms are increasingly gaining research interest due to their linkage information exploration feature. Two main mechanisms which contribute towards the success of the algorithms are probabilistic modeling and sampling method. Recent attention has been directed towards the development of probabilistic building technique. However, research on the sampling approach is less developed. Thus, this paper carries out an investigation on sampling technique for a novel multi-objective estimation of distribution algorithm - multi-objective restricted Boltzmann machine. Two variants of a new sampling technique based on energy value of the solutions in the trained network are proposed to improve the efficiency of the algorithm. Probabilistic information which is usually clamped into marginal probability distribution may hinder the algorithm in producing solutions that have high linkage dependency between variables. The proposed approach will overcome this limitation of probabilistic modeling in restricted Boltzmann machine. The empirical investigation shows that the proposed algorithm gives promising result in term of convergence and convergence rate.

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# A Probabilistic Graphical Model For Estimation of Distribution Algorithms

Ding, Caichang Liu, Yuanchao

we consider the topic of building a probability model - a Bayesian network - from a given set of data. When there is no additive composition known for the given problem, the dependencies of the variables can be learned from the data set. In the context of Estimation of Distribution algorithm, learning a Bayesian Network from the selected population and then sampling from this model are the basic steps of Learning FDA. Usually, Bayesian networks are learned using the "score and search" paradigm. This means that there is a score which measures the quality of the network and a local search which finds within a neighborhood the network which maximizes the score.

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# An Efficient Estimation of Distribution Algorithm for Job Shop Scheduling Problem

He, Xiao-juan Zeng, Jian-chao Xue, Song-dong Wang, Li-fang

An estimation of distribution algorithm with probability model based on permutation information of neighboring operations for job shop scheduling problem was proposed. The probability model was given using frequency information of pair-wise operations neighboring. Then the structure of optimal individual was marked and the operations of optimal individual were partitioned to some independent sub-blocks. To avoid repeating search in same area and improve search speed, each sub-block was taken as a whole to be adjusted. Also, stochastic adjustment to the operations within each sub-block was introduced to enhance the local search ability. The experimental results show that the proposed algorithm is more robust and efficient.

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# An Estimation of Distribution Algorithm Based Portfolio Selection Approach

Xu, Rui-Tian Zhang, Jun Liu, Ou Huang, Rui-Zhang

A portfolio selection problem is about finding an optimal scheme to allocate a fixed amount of capital to a set of available assets. The optimal scheme is very helpful for investors in making decisions. However, finding the optimal scheme is difficult and time-consuming especially when the number of assets is large and some actual investment constraints are considered. This paper proposes a new approach based on estimation of distribution algorithms (EDAs) for solving a cardinality constrained portfolio selection (CCPS) problem. The proposed algorithm, termed PBILCCPS, hybridizes an EDA called population-based incremental learning (PBIL) algorithm and a continuous PBIL (PBILc) algorithm, to optimize the selection of assets and the allocation of capital respectively. The proposed algorithm adopts an adaptive parameter control strategy and an elitist strategy. The performance of the proposed algorithm is compared with a genetic algorithm and a particle swarm optimization algorithm. The results demonstrate that the proposed algorithm can achieve a satisfactory result for portfolio selection and perform well in searching nondominated portfolios with high expected returns.

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# Efficient Resource Minimization Scheme for Network Coding-Assisted Multicast System

Hejazi, Seyed Amin Naeem, M. Lee, D. C.

In this paper, we consider the problem of minimizing the resources used for network coding (MRUNC) while achieving the desired throughput in a multicast system. The problem of minimizing the number of network coding links is NP-hard. In this paper we propose a low-complexity Estimation of Distribution Algorithm (EDA) for MRUNC. Our EDA is applicable to the network with and without cycles. The numerical results show the effectiveness of the proposed method over previously proposed algorithms.

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# CONTROLLING CHAOS BY AN IMPROVED ESTIMATION OF DISTRIBUTION ALGORITHM

Huang, Xingli Jia, Peifa Liu, Bo

Control and synchronization of chaotic systems are important issues in nonlinear sciences. This paper proposes an effective estimation of distribution algorithm (EDA)-based memetic algorithm (MA) to direct the orbits of discrete chaotic dynamical systems as well as to synchronize chaotic systems, which could be formulated as complex multi-modal numerical optimization problems. In EDA-based MA (EDAMA), both EDA-based searching operators and simulated annealing (SA) based local searching operators are designed to balance the exploration and exploitation abilities. On the other hand, global information provided by EDA is combined with local information from SA to create better solutions. In particular, to enrich the searching behaviors and to avoid premature convergence, SA-based local search is designed and incorporated into EDAMA. To balance the exploration and exploitation abilities, after the standard EDA-based searching operation, SA-based local search is probabilistically applied to some good solutions selected by using a roulette wheel mechanism with a specified probability. Numerical simulations based on Henon Map demonstrate the effectiveness and efficiency of EDAMA, and the effects of some parameters are investigated as well.

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# Probabilistic Model Building Genetic Network Programming Using Multiple Probability Vectors

Li, Xianneng Mabu, Shingo Mainali, Manoj K. Hirasawa, Kotaro

As an extension of GA and GP, a new evolutionary algorithm named Genetic Network Programming (GNP) has been proposed. GNP uses the directed graph structure to represent its solutions, which can express the dynamic environment efficiently. The reusable nodes of GNP can construct compact structures, leading to a good performance in complex problems. In addition, a probabilistic model building GNP named GNP with Estimation of Distribution Algorithm (GNP-EDA) has been proposed to improve the evolution efficiency. GNP-EDA outperforms the conventional GNP by constructing a probabilistic model by estimating the probability distribution from the selected elite individuals of the previous generation. In this paper, a probabilistic model building GNP with multiple probability vectors (PMBGNP(M)) is proposed. In the proposed algorithm, multiple probability vectors are used in order to escape from premature convergence, and genetic operations like crossover and mutation are carried out to the probability vectors to maintain the diversities of the populations. The proposed algorithm is applied to the controller of autonomous robots and its performance is evaluated.

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# Toward an Estimation of Distribution Algorithm for the Evolution of Artificial Neural Networks

Holkar, Graham dos Santos, Marcus Vinicius

This paper presents the preliminary results of a unique method of neuroevolution called Probabilistic Developmental Neuroevolution (PDNE). PDNE builds upon Gene Expression Programming (GEP) and Probabilistic Incremental Program Evolution (PIPE). Instead of building a Probabilistic Prototype Tree, as in PIPE, a Probabilistic Prototype Chromosome is built. The chromosome has a similar structure to a GEP chromosome (head, tail, and weight domain) and contains probabilities for each element of the gene. With this methodology, neural networks can be expressed in a similar manner to GEP, and solutions can be evolved via an Estimation of Distribution Algorithm. Preliminary results show promise, but further work is required to match the results of GEP.

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# GAIS: A Gaussian Artificial Immune System for Continuous Optimization

Castro, Pablo A. D. Von Zuben, Fernando J.

This paper proposes a Gaussian Artificial Immune System (CATS) to deal effectively with building blocks (high-quality partial solutions coded in the solution vector) in continuous optimization problems. By replacing the mutation and cloning operators with a probabilistic model, more specifically a Gaussian network representing the joint distribution of promising solutions, GAIS takes into account the relationships among the variables of the problem, avoiding the disruption of already obtained high-quality partial solutions. Two versions of the algorithm were developed. In the first one, the estimation of the joint probability distribution is achieved by means of a single multivariate Gaussian distribution. In the second version, the estimation is carried out using a Gaussian mixture model. The algorithms were applied to eight benchmarks and the results compared with those produced by an immune-inspired algorithm and an estimation of distribution algorithm.

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# A Hybrid Evolutionary Algorithm Based on Alopex and Estimation of Distribution Algorithm and Its Application for Optimization

Li, Shaojun Li, Fei Mei, Zhenzhen

Alopex is a correlation-based algorithm. which shares characteristics of both gradient descent approach and simulated annealing It has been successfully applied to continuous and combinatorial optimization problems for years Estimation of Distribution Algorithms (EDAs) is a class or novel evolutionary algorithms (EAs) proposed in recent years Compared with the traditional EAs, it possesses unique evolutionary characteristics In this paper, a hybrid evolutionary algorithm (EDA-Alopex) is proposed. which integrates the merits of both Alopex and EDA. and obtains mole evolutionary information than these two approaches The new algorithm is tested with several benchmark functions, numerical case study results demonstrate that EDA-Alopex on both EDA and AEA. especially for the complex multi-modal functions Finally, the proposed algorithm Is investigated on high-dimensional and multi-peaks benchmark functions, and it also achieves satisfactory results

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# Adapting Heuristic Mastermind Strategies to Evolutionary Algorithms

Runarsson, Thomas Philip Merelo-Guervos, Juan J.

The art of solving the Mastermind puzzle was initiated by Donald Knuth and is already more than thirty years old; despite that, it still receives much attention in operational research and computer games journals, not to mention the nature-inspired stochastic algorithm literature. In this paper we try to suggest a strategy that will allow nature-inspired algorithms to obtain results as good as those based on exhaustive search strategies; in order to do that, we first review, compare and improve current approaches to solving the puzzle; then we test one of these strategies with an estimation of distribution algorithm. Finally, we try to find a strategy that falls short of being exhaustive, and is then amenable for inclusion in nature inspired algorithms (such as evolutionary of particle swarm algorithms). This paper proves that by the incorporation of what we call local entropy into the fitness function of the evolutionary algorithm it becomes a better player than a random one, and gives a rule of thumb on how to incorporate the best heuristic strategies to evolutionary algorithms without incurring in an excessive computational cost.

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# Using Probabilistic Dependencies Improves the Search of Conductance-Based Compartmental Neuron Models

Santana, Roberto Bielza, Concha Larranaga, Pedro

Conductance-based compartmental neuron models are traditionally used to investigate the electrophysiological properties of neurons. These models require a number of parameters to be adjusted to biological experimental data and this question can be posed as an optimization problem. In this paper we investigate the behavior of different estimation of distribution algorithms (EDAs) for this problem. We focus on studying the influence that ate interactions between the neuron model conductances have in the complexity of the optimization problem. We support evidence that the use of these interactions during the optimization process can improve the EDA behavior.

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