# An Evolutionary Algorithm That Makes Decision Based on the Entire Previous Search History

Chow, Chi Kin Yuen, Shiu Yin

In this paper, we report a novel evolutionary algorithm that enhances its performance by utilizing the entire previous search history. The proposed algorithm, namely history driven evolutionary algorithm (HdEA), employs a binary space partitioning tree structure to memorize the positions and the fitness values of the evaluated solutions. Benefiting from the space partitioning scheme, a fast fitness function approximation using the archive is obtained. The approximation is used to improve the mutation strategy in HdEA. The resultant mutation operator is parameter-less, anisotropic, and adaptive. Moreover, the mutation operator naturally avoids the generation of out-of-bound solutions. The performance of HdEA is tested on 34 benchmark functions with dimensions ranging from 2 to 40. We also provide a performance comparison of HdEA with eight benchmark evolutionary algorithms, including a real coded genetic algorithm, differential evolution, two improved differential evolution, covariance matrix adaptation evolution strategy, two improved particle swarm optimization, and an estimation of distribution algorithm. Seen from the experimental results, HdEA outperforms the other algorithms for multimodal function optimization.

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# Application of L-EDA in metabonomics data handling: global metabolite profiling and potential biomarker discovery of epithelial ovarian cancer prognosis

Chen, Jing Zhang, Yang Zhang, Xiaoyan Cao, Rui Chen, Shili Huang, Qiang Lu, Xin Wan, Xiaoping Wu, Xiaohua Xu, Congjian Xu, Guowang Lin, Xiaohui

Solution capacity limited estimation of distribution algorithm (L-EDA) is proposed and applied to ovarian cancer prognosis biomarker discovery to expatiate on its potential in metabonomics studies. Sera from healthy women, epithelial ovarian cancer (EOC), recurrent EOC and non-recurrent EOC patients were analyzed by liquid chromatography-mass spectrometry. The metabolite data were processed by L-EDA to discover potential EOC prognosis biomarkers. After L-EDA filtration, 78 out of 714 variables were selected, and the relationships among four groups were visualized by principle component analysis, it was observed that with the L-EDA filtered variables, non-recurrent EOC and recurrent EOC groups could be separated, which was not possible with the initial data. Five metabolites (six variables) with P &lt; 0.05 in Wilcoxon test were discovered as potential EOC prognosis biomarkers, and their classification accuracy rates were 86.9% for recurrent EOC and non-recurrent EOC, and 88.7% for healthy + non-recurrent EOC and EOC + recurrent EOC. The results show that L-EDA is a powerful tool for potential biomarker discovery in metabonomics study.

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# Combining tabu Hopfield network and estimation of distribution for unconstrained binary quadratic programming problem

Wang, Jiahai Zhou, Ying Yin, Jian

Unconstrained binary quadratic programming problem (UBQP) consists in maximizing a quadratic 0-1 function. It is a well known NP-hard problem and is considered as a unified model for a variety of combinatorial optimization problems. This paper combines a tabu Hopfield neural network (HNN) (THNN) with estimation of distribution algorithm (EDA), and thus a THNN-EDA is proposed for the UBQP. In the THNN, the tabu rule, instead of the original updating rule of the HNN, is used to govern the state transition or updating of neurons to search for the global minimum of the energy function. A probability vector in EDA model is built to characterize the distribution of promising solutions in the search space, and then the THNN is guided by the global search information in EDA model to search better solution in the promising region. Thus, the short term memory of the tabu mechanism in the THNN cooperates with the long term memory mechanism in the EDA to help the network escape from local minima. The THNN-EDA is tested on 21 UBQP benchmark problems with the size ranging from 3000 to 7000, and 48 maximum cut benchmark problems, a special case of the UBQP, with the size ranging from 512 to 3375. Simulation results show that the THNN-EDA is better than the other HNN based algorithms, and is better than or competitive with metaheuristic algorithms and state-of-the-art algorithms. (C) 2011 Elsevier Ltd. All rights reserved.

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# A Bayesian Estimation of Distribution Algorithm Approach to the Definition of Linear Antenna Arrays Excitations

Isla, Julio Ochoa, Alberto

This paper introduces and investigates the family of aperture distributions whose members have the best Side Lobe Ratio (SLR) for a given Inverse Dynamic Range Ratio (IDRR). An optimization approach based on Estimation of Distributions Algorithms is used to find the family instances. The paper shows that the family has limiting distributions with a number of interesting properties, e.g. it has a good tradeoff between beamwidth and SLR and has the best IDRR for a given beamwidth. The numerical results allow us to conclude the following: 1) the IDRR impacts the complexity of the problem, i.e. the larger the IDRR the easier the optimization. 2) linear entropic mutation improves the performance of the algorithms and reduces the population size requirements. 3) the independence model seems to be adequate for very large IDRR but fails dramatically for the other cases.

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# A discrete artificial bee colony algorithm for the total flowtime minimization in permutation flow shops

Tasgetiren, M. Fatih Pan, Quan-Ke Suganthan, P. N. Chen, Angela H-L

Obtaining an optimal solution for a permutation flowshop scheduling problem with the total flowtime criterion in a reasonable computational timeframe using traditional approaches and optimization tools has been a challenge. This paper presents a discrete artificial bee colony algorithm hybridized with a variant of iterated greedy algorithms to find the permutation that gives the smallest total flowtime. Iterated greedy algorithms are comprised of local search procedures based on insertion and swap neighborhood structures. In the same context, we also consider a discrete differential evolution algorithm from our previous work. The performance of the proposed algorithms is tested on the well-known benchmark suite of Taillard. The highly effective performance of the discrete artificial bee colony and hybrid differential evolution algorithms is compared against the best performing algorithms from the existing literature in terms of both solution quality and CPU times. Ultimately, 44 out of the 90 best known solutions provided very recently by the best performing estimation of distribution and genetic local search algorithms are further improved by the proposed algorithms with short-term searches. The solutions known to be the best to date are reported for the benchmark suite of Taillard with long-term searches, as well. (C) 2011 Elsevier Inc. All rights reserved.

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# Evolutionary algorithms for solving multi-objective travelling salesman problem

Shim, Vui Ann Tan, Kay Chen Chia, Jun Yong Chong, Jin Kiat

This paper studies the application of evolutionary algorithms for bi-objective travelling salesman problem. Two evolutionary algorithms, including estimation of distribution algorithm (EDA) and genetic algorithm (GA), are considered. The solution to this problem is a set of trade-off alternatives. The problem is solved by optimizing the order of the cities so as to simultaneously minimize the two objectives of travelling distance and travelling cost incurred by the travelling salesman. In this paper, binary-representation-based evolutionary algorithms are replaced with an integer-representation. Three existing EDAs are altered to use this integer-representation, namely restricted Boltzmann machine (RBM), univariate marginal distribution algorithm (UMDA), and population-based incremental learning (PBIL). Each city is associated with a representative integer, and the probability of any of this representative integer to be located in any position of the chromosome is constructed through the modeling approach of the EDAs. New sequences of cities are obtained by sampling from the probabilistic model. A refinement operator and a local search operator are proposed in this piece of work. The EDAs are subsequently hybridized with GA in order to complement the limitations of both algorithms. The effect that each of these operators has on the quality of the solutions are investigated. Empirical results show that the hybrid algorithms are capable of finding a set of good trade-off solutions.

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# EA/G-GA for Single Machine Scheduling Problems with Earliness/Tardiness Costs

Chen, Shih-Hsin Chen, Min-Chih Chang, Pei-Chann Chen, Yuh-Min

An Estimation of Distribution Algorithm (EDA), which depends on explicitly sampling mechanisms based on probabilistic models with information extracted from the parental solutions to generate new solutions, has constituted one of the major research areas in the field of evolutionary computation. The fact that no genetic operators are used in EDAs is a major characteristic differentiating EDAs from other genetic algorithms (GAs). This advantage, however, could lead to premature convergence of EDAs as the probabilistic models are no longer generating diversified solutions. In our previous research [1], we have presented the evidences that EDAs suffer from the drawback of premature convergency, thus several important guidelines are provided for the design of effective EDAs. In this paper, we validated one guideline for incorporating other meta-heuristics into the EDAs. An algorithm named "EA/G-GA" is proposed by selecting a well-known EDA, EA/G, to work with GAs. The proposed algorithm was tested on the NP-Hard single machine scheduling problems with the total weighted earliness/tardiness cost in a just-in-time environment. The experimental results indicated that the EA/G-GA outperforms the compared algorithms statistically significantly across different stopping criteria and demonstrated the robustness of the proposed algorithm. Consequently, this paper is of interest and importance in the field of EDAs.

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# Memetic clonal selection algorithm with EDA vaccination for unconstrained binary quadratic programming problems

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

This paper presents a memetic clonal selection algorithm (MCSA) with estimation of distribution algorithm (EDA) vaccination, named MCSA-EDA, for the unconstrained binary quadratic programming problem (UBQP). In order to improve the performance of the conventional clonal selection algorithm (CSA), three components are adopted in MCSA-EDA. First, to compensate for the absence of recombination among different antibodies, an EDA vaccination is designed and incorporated into CSA. Second, to keep the diversity of the population, a fitness uniform selection scheme (FUSS) is adopted as a selection operator. Third, to enhance the exploitation ability of CSA, an adaptive tabu search (TS) with feedback mechanism is introduced. Thus, MCSA-EDA can overcome the deficiencies of CSA and further search better solutions. MCSA-EDA is tested on a series of UBQP with size up to 7000 variables. Simulation results show that MCSA-EDA is effective for improving the performance of the conventional CSA and is better than or at least competitive with other existing metaheuristic algorithms. (C) 2010 Elsevier Ltd. All rights reserved.

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# Estimation of distribution algorithm for permutation flow shops with total flowtime minimization

Zhang, Yi Li, Xiaoping

In this paper, an Estimation of Distribution Algorithm (EDA) is proposed for permutation flow shops to minimize total flowtime. Longest Common Subsequence (LCS) is incorporated into the probability distribution model to mine good "genes". Different from common EDAs, each offspring individual is produced from a seed, which is selected from the population by the roulette method. The LCS between the seed individual and the best solution found so far is regarded as good "genes". which are inherited by offspring with a probability less than 100% to guarantee the population diversity. An effective Variable Neighborhood Search (VNS) is integrated into the proposed EDA to further improve the performance. Experimental results show that the inheritance of good "genes" obtained by LCS can improve the performance of the proposed EDA. The proposed hybrid EDA outperforms other existing algorithms for the considered problem in the literature. Furthermore, the proposed hybrid EDA improved 42 out of 90 current best solutions for Taillard benchmark instances. (C) 2011 Elsevier Ltd. All rights reserved.

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# Using selfish gene theory to construct mutual information and entropy based clusters for bivariate optimizations

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

This paper proposes a new approach named SGMIEC in the field of estimation of distribution algorithm (EDA). 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 and entropy based cluster (MIEC) 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, SGMIEC often performs better in convergent reliability, convergent velocity and convergent process.

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

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

Pressurised Heavy Water Reactors (PHWRs) are based on Natural Uranium (NU) fuel and heavy water as moderator and coolant. At the beginning of reactor life of PHWR, if all NU bundles are loaded, the power peaking is high and full power cannot be drawn. In order to draw full power, it is possible to flatten the power in fresh core by loading some depleted uranium (DU) (or Thorium) bundles. The determination of the best possible locations of DU bundles which maximize economy and preserve safety is a constrained combinatorial optimization problem. This paper presents optimization of DU bundle distribution in the fresh core of the 700 MWe PHWR. An evolutionary technique based on Estimation of Distribution Algorithm (EDA) is used to determine the optimum DU loading pattern. The best suitable locations for DU bundles are determined using EDA. In order to meet some additional constraints, some additional DU bundles are placed at 11th and 12th bundle locations in few channels. These channels are selected manually. The overall aim of the optimization is to maximize K-effective and get 100% full power without violating safety parameters such as maximum permissible bundle power, channel power peaking factor and permitted reactivity worth in shut-down system. The optimum configuration is explicitly presented. (C) 2010 Elsevier Ltd. All rights reserved.

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# A hybrid particle swarm optimization with estimation of distribution algorithm for solving permutation flowshop scheduling problem

Liu, Hongcheng Gao, Liang Pan, Quanke

In this paper we propose PSO-EDA, a hybrid particle swarm optimization (PSO) with estimation of distribution algorithm (EDA) to solve permutation flowshop scheduling problem (PFSP). PFSP is an NP-complete problem, for which PSO was recently applied. The social cognition in the metaphor of canonical PSO is incomplete, since information conveyed in the non-gbest particles is lost. Also, the intelligence of the particles is totally neglected by the canonical PSO and most of other literatures. To tackle such problems, we propose to enable the sharing of information from the collective experience of the swarm by hybridizing an EDA operator with PSO and to add the primitive intelligence to each particle by using a local search mechanism. To enhance the performance of the algorithm proposed, a new local search algorithm, the minimization-of-waiting-time local search (MWL), is applied. The computational experiment on different benchmark suites in PFSP, in which two new best known solutions have been found, shows a superiority of PSO-EDA over other counterpart algorithms in terms of accuracy. (C) 2010 Elsevier Ltd. All rights reserved.

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# Δ-Entropy: Definition, properties and applications in system identification with quantized data

Chen, Badong Zhu, Yu Hu, Jinchun Principe, Jose C.

Recently, the minimum error entropy criterion, an information theoretic alternative to the traditional mean square error criterion, has been successfully used in the contexts of machine learning and signal processing. For system identification, however, the MEE criterion will be no longer suitable if the training data are discrete-valued, since minimizing error's discrete entropy cannot constrain error's dispersion. In this paper, to make the MEE criterion suitable for the discrete-valued data cases, we give a new entropy definition for the discrete random variables, i.e. the Delta-entropy, based on Riemann sums for finite size partitions. A probability weighted formula is established to calculate the average partition. This new entropy retains some important properties of the differential entropy and reduces to discrete entropy under certain conditions. Unlike discrete entropy, the Delta-entropy is sensitive to the dynamic range of the data, and can be used as a superior optimality criterion in system identification problems. Also, we present a plug-in estimate of Delta-entropy, analyze its asymptotic behavior and explore the links to the kernel based and m-spacing based estimates for differential entropy. Finally, the Delta-entropy criterion is applied in system identification with coarsely quantized input-output data to search for the optimum parameter set. Monte Carlo simulations demonstrate the performance improvement that may be achieved with the Delta-entropy criterion. Published by Elsevier Inc.

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# MB-GNG: Addressing drawbacks in multi-objective optimization estimation of distribution algorithms

Marti, Luis Garcia, Jesus Berlanga, Antonio Coello Coello, Carlos A. Molina, Jose M.

We examine the model-building issue related to multi-objective estimation of distribution algorithms (MOEDAs) and show that some of their, as yet overlooked, characteristics render most current MOEDAs unviable when addressing optimization problems with many objectives. We propose a novel model-building growing neural gas (MB-GNG) network that is specially devised for properly dealing with that issue and therefore yields a better performance. Experiments are conducted in order to show from an empirical point of view the advantages of the new algorithm. (c) 2011 Elsevier B.V. All rights reserved.

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# Environment identification-based memory scheme for estimation of distribution algorithms in dynamic environments

Peng, Xingguang Gao, Xiaoguang Yang, Shengxiang

In estimation of distribution algorithms (EDAs), the joint probability distribution of high-performance solutions is presented by a probability model. This means that the priority search areas of the solution space are characterized by the probability model. From this point of view, an environment identification-based memory management scheme (EI-MMS) is proposed to adapt binary-coded EDAs to solve dynamic optimization problems (DOPs). Within this scheme, the probability models that characterize the search space of the changing environment are stored and retrieved to adapt EDAs according to environmental changes. A diversity loss correction scheme and a boundary correction scheme are combined to counteract the diversity loss during the static evolutionary process of each environment. Experimental results show the validity of the EI-MMS and indicate that the EI-MMS can be applied to any binary-coded EDAs. In comparison with three state-of-the-art algorithms, the univariate marginal distribution algorithm (UMDA) using the EI-MMS performs better when solving three decomposable DOPs. In order to understand the EI-MMS more deeply, the sensitivity analysis of parameters is also carried out in this paper.

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# Learning Ensembles of Neural Networks by Means of a Bayesian Artificial Immune System

Dalbem Castro, Pablo A. Von Zuben, Fernando Jose

In this paper, we apply an immune-inspired approach to design ensembles of heterogeneous neural networks for classification problems. Our proposal, called Bayesian artificial immune system, is an estimation of distribution algorithm that replaces the traditional mutation and cloning operators with a probabilistic model, more specifically a Bayesian network, representing the joint distribution of promising solutions. Among the additional attributes provided by the Bayesian framework inserted into an immune-inspired search algorithm are the automatic control of the population size along the search and the inherent ability to promote and preserve diversity among the candidate solutions. Both are attributes generally absent from alternative estimation of distribution algorithms, and both were shown to be useful attributes when implementing the generation and selection of components of the ensemble, thus leading to high-performance classifiers. Several aspects of the design are illustrated in practical applications, including a comparative analysis with other attempts to synthesize ensembles.

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# Solving the Orbital Transformation Problem Considering Time and Fuel Cost as Optimal Index based on EDA

Zhang, Qixin Sun, Fuchun Min, Haibo Wang, Yafeng

This paper presents the optimal considering of time and fuel in on-orbit servicing space shuttle orbit maneuver. Firstly, the eigen velocity of rendezvous in on-orbit servicing space shuttle using two impulses is derived according to C-W Equation. Based on that, optimal rendezvous object considering of time and fuel is constructed. By analyzing the impact of single and mixed index on the system, the mixed index of time-energy relations are discussed. This paper proposes the comparison of results comes from EDA(Estimation of distribution algorithm) and GA(Genetic algorithm). Simulation results indicate that the EDA algorithm is feasible and effective.

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# EDA-based Joint Power, Subcarrier Allocation and Relay Assignment Scheme for Multiuser Relaying in OFDMA-based Cognitive Radio Systems

Oberoi, J. S. Pareek, U. Naeem, M. Lee, D. C.

In this paper, we present an interference and channel conditions aware multiple relay assignment and subcarrier allocation scheme for OFDMA based cognitive radio systems employing cooperative transmission using Decode and Forward (DF) technique. We focus on the problem of assigning the relays, the relay powers and allocating the subcarriers to the destination nodes using the sum capacity of the cognitive radio system as the objective function to be maximized under the constraint of maximum acceptable levels of interference for the primary users (PU). The computational complexity of this assignment using exhaustive search algorithm grows exponentially with the number of relays, subcarriers and receivers. Thus we propose Estimation of Distribution Algorithm (EDA) for this assignment problem. EDA is a probabilistic evolutionary algorithm which updates its population at each iteration on the basis of the probability densities obtained from the population of superior candidates evaluated and chosen at the previous iteration. EDA employed with our allocation scheme has low computational complexity and its performance is comparable to the Upper Bound of the solution as shown by various simulation results.

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# Flexible Learning of k-Dependence Bayesian Network Classifiers

Rubio, Arcadio Gamez, Jose A.

In this paper we present an extension to the classical k-dependence Bayesian network classifier algorithm.

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# An Estimation of Distribution Algorithm based on Nonparametric Density Estimation

Zhou, Luhan Zhou, Aimin Zhang, Guixu Shi, Chuan

Probabilistic models play a key role in an estimation of distribution algorithm(EDA). Generally, the form of a probabilistic model has to be chosen before executing an EDA. In each generation, the probabilistic model parameters will be estimated by training the model on a set of selected individuals and new individuals are then sampled from the probabilistic model. In this paper, we propose to use probabilistic models in a different way: firstly generate a set of candidate points, then find some as offspring solutions by a filter which is based on a nonparametric density estimation method. Based on this idea, we propose a nonparametric estimation of distribution algorithm (nEDA) for global optimization. The major differences between nEDA and traditional EDAs are (1) nEDA uses a generating-filtering strategy to create new solutions while traditional EDAs use a model building-sampling strategy to generate solutions, and (2) nEDA utilizes a nonparametric density model with traditional EDAs usually utilize parametric density models. nEDA is compared with a traditional EDA which is based on Gaussian model on a set of benchmark problems. The preliminary experimental results show that nEDA is promising for dealing with global optimization problems.

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# A Novel Estimation of Distribution Algorithm Using Graph-based Chromosome Representation and Reinforcement Learning

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

This paper proposed a novel EDA, where a directed graph network is used to represent its chromosome. In the proposed algorithm, a probabilistic model is constructed from the promising individuals of the current generation using reinforcement learning, and used to produce the new population. The node connection probability is studied to develop the probabilistic model, therefore pairwise interactions can be demonstrated to identify and recombine building blocks in the proposed algorithm. The proposed algorithm is applied to a problem of agent control, i.e., autonomous robot control. The experimental results show the superiority of the proposed algorithm comparing with the conventional algorithms.

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# The Research of Q Learning-Based Estimation of Distribution Algorithm

Hu Yugang

This paper focuses on the theory of estimation of distribution algorithms. First, elaborated the idea of estimation of distribution algorithms, And then for the limitations of solving complex optimization problems, proposed Q Learning-Based Estimation of Distribution Algorithm. The Q learning algorithm is introduced into evolutionary computation, through the Agent and group interaction, to achieve a probability model of adaptive updates. Test functions using six classical comparative experiment, the results show that the algorithm performance is stable, running time is short, with a strong global search ability, is an efficient solving algorithm for function optimization problems.

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# Dependence Trees with Copula Selection for Continuous Estimation of Distribution Algorithms

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

In this paper, a new Estimation of Distribution Algorithm (EDA) is presented. The proposed algorithm employs a dependency tree as a graphical model and bivariate copula functions for modeling relationships between pairwise variables. By selecting copula functions it is possible to build a very flexible joint distribution as a probabilistic model. The experimental results show that the proposed algorithm has a better performance than EDAs based on Gaussian assumptions.

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# Global Optimization with the Gaussian Polytree EDA

Segovia Dominguez, Ignacio Hernandez Aguirre, Arturo Villa Diharce, Enrique

This paper introduces the Gaussian polytree estimation of distribution algorithm, a new construction method, and its application to estimation of distribution algorithms in continuous variables. The variables are assumed to be Gaussian. The construction of the tree and the edges orientation algorithm are based on information theoretic concepts such as mutual information and conditional mutual information. The proposed Gaussian polytree estimation of distribution algorithm is applied to a set of benchmark functions. The experimental results show that the approach is robust, comparisons are provided.

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# A Multi-population Parallel Estimation of Distribution Algorithms Based on Clayton and Gumbel Copulas

Chang, Chunyan Wang, Lifang

The idea of multi-population parallel strategy and the copula theory are introduced into the Estimation of Distribution Algorithm (EDA), and a new parallel EDA is proposed in this paper. In this algorithm, the population is divided into some subpopulations. Different copula is used to estimate the distribution model in each subpopulation. Two copulas, Clayton and Gumbel, are used in this paper. To estimate the distribution function is to estimate the copula and the margins. New individuals are generated according to the copula and the margins. In order to increase the diversity of the subpopulation, the elites of one subpopulation are learned by the other subpopulation. The experiments show the proposed algorithm performs better than the basic copula EDA and some classical EDAs in speed and in precision.

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# Opposition-Based Learning Estimation of Distribution Algorithm with Gaussian Copulas and Its Application to Placement of RFID Readers

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

Estimation of distribution algorithms are a class of optimization algorithms based on probability distribution model. In this paper, we propose an improved estimation of distribution algorithm using opposition-based learning and Gaussian copulas. The improved algorithm employs multivariate Gaussian copulas to construct probability distribution model and uses opposition-based learning for population initialization and new population generation. 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. Then, the opposite numbers have also been utilized to improve the convergence performances. The improved algorithm is applied to some benchmark functions and optimal placement of readers in RFID networks. The relative experimental results show that the improved algorithm has better performance than original version of estimation of distribution algorithm and is effective in the optimal placement of readers in REID networks.

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# Estimation of Distribution Algorithm for the Quay Crane Scheduling Problem

Exposito Izquierdo, Christopher Gonazalez Velarde, Jose Luis Melian Batista, Belen Marcos Moreno-Vega, J.

Estimation of Distribution Algorithms (EDA) are a type of optimization techniques that belong to evolutionary computation. Its operation is based on the use of a probabilistic model, which tries to reach promising regions through statistical information concerning to the individuals that belong to the population. In this work, several solution approaches based on the EDA field are presented in order to solve the Quay Crane Scheduling Problem (QCSP). QCSP consists of obtaining a schedule that minimizes the service time of a container vessel given a set of tasks (loading and unloading operations to/from) by means of the available quay cranes at a container terminal. The experimental results confirm that such algorithms are suitable for solving the QCSP and perform a wide exploration of the solution space using reduced computational times.

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# An New Estimation of Distribution Algorithm Based Edge Histogram Model for Flexible Job-Shop Problem

He, Xiaojuan Zeng, Jianchao Xue, Songdong Wang, Lifang

An estimation of distribution algorithm for flexible 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. Each sub-block was taken as a whole to be adjusted to avoid repeating search in same area and improve search speed. The experimental results show that the proposed algorithm is efficient for Flexible Job-Shop Problems.

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# Real-coded Estimation of Distribution Algorithm by Using Probabilistic Models with Multiple Learning Rates

Nakao, Masahiro Hiroyasu, Tomoyuki Miki, Mitsunori Yokouchi, Hisatake Yoshimi, Masato

Here, a new Real-coded Estimation of Distribution Algorithm (EDA) is proposed. The proposed EDA is called Real-coded EDA using Multiple Probabilistic Models (RMM). RMM includes multiple types of probabilistic models with different learning rates and diversities. The search capability of RMM was examined through several types of continuous test function. The results indicated that the search capability of RMM is better than or equivalent to that of existing Real-coded EDAs. Since better searching points are distributed for other probabilistic models positively, RMM can discover the global optimum in the early stages of the search.

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# Univariate Marginal Distribution Algorithm in Combination with Extremal Optimization (EO, GEO)

Hashemi, Mitra Meybodi, Mohammad Reza

The 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 dose 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 represent the performance of the proposed algorithm on two NP-hard problems, multi processor scheduling problem and graph hi-partitioning problem.

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# Automatic knot adjustment for B-spline surface approximation (Retracted Article)

Li Pingping Zhao Xiuyang Yang Bo

Fairing B-spline surface is regarded as one major precondition for surface reconstruction. To obtain a good surface approximation, a novel method is proposed in this paper. The knots of the B-spline surface are treated as variables, and are optimized by the estimation of distribution algorithm. The initial knots are decided by the parameterization of the measured data points. The experiment results show that this method can obtain more precise surface approximate. (C) 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the Organizers of 2011 International Conference on Energy and Environmental Science.

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# On the Effect of Environment-Triggered Population Diversity Compensation Methods for Memory Enhanced UMDA

Peng Xingguang Xu Demin Zhang Fubin

This paper focuses on the effect of population diversity to environment identification-based memory scheme (EI-MMS) which heuristically compensates population diversity through the storage and retrieving process of historic information. We introduced several diversity compensation measures and combined them with EI-MMS based univariate marginal distribution algorithm (UMDA) from two aspects. First, a basic diversity compensation measure was used to fight against the inherent diversity loss of UMDA. Second, two environment-triggered compensation measures were added in the sense of dynamic environment. Based on the experimental results on three dynamic test problems, the dynamics of population diversity of the corresponding EI-MMS based UMDAs were analyzed and several conclusions about how does the population diversity affect the performance of the algorithm in dynamic environments were drawn.

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# Efficient model building in competent genetic algorithms using DSM clustering

Nikanjam, Amin Sharifi, Hadi Rahmani, Adel T.

Detecting multivariate interactions between the variables of a problem is a challenge in traditional genetic algorithms (GAs). This issue has been addressed in the literature as the linkage learning problem. It is widely acknowledged that the success of GA in solving any problem depends on the proper detection of multivariate interactions in the problem. Different approaches have thus been proposed to detect and represent such interactions. Estimation of distribution algorithms (EDAs) are amongst these approaches that have been successfully applied to a wide range of hard optimization problems. They build a model of the problem to detect multivariate interactions, but the model building process is often computationally intensive. In this paper, we propose a new clustering algorithm that turns pair-wise interactions in a dependency structure matrix (DSM) into an interaction model efficiently. The model building process is carried out before the evolutionary algorithm to save computational burden. The accurate interaction model obtained in this way is then used to perform an effective recombination of building blocks (BBs) in the GA. We applied the proposed approach to solve exemplar hard optimization problems with different types of linkages to show the effectiveness and efficiency of the proposed approach. Theoretical analysis and experiments showed that the building of an accurate model requires O(n log(n)) number of fitness evaluations. The comparison of the proposed approach with some existing algorithms revealed that the efficiency of the model building process is enhanced significantly.

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# Multi-objective Phylogenetic Algorithm: Solving Multi-objective Decomposable Deceptive Problems

Martins, Jean Paulo Mineiro Soares, Antonio Helson Vargas, Danilo Vasconcellos Botazzo Delbem, Alexandre Claudio

In general, Multi-objective Evolutionary Algorithms do not guarantee find solutions in the Pareto-optimal set. We propose a new approach for solving decomposable deceptive multi-objective problems that can find all solutions of the Pareto-optimal set. Basically, the proposed approach starts by decomposing the problem into subproblems and, then, combining the found solutions. The resultant approach is a Multi-objective Estimation of Distribution Algorithm for solving relatively complex multi-objective decomposable problems, using a probabilistic model based on a phylogenetic tree. The results show that, for the tested problem, the algorithm can efficiently find all the solutions of the Pareto-optimal set, with better scaling than the hierarchical Bayesian Optimization Algorithm and other algorithms of the state of art.

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# Multi-objective Optimization with Joint Probabilistic Modeling of Objectives and Variables

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

The objective values information can be incorporated into the evolutionary algorithms based on probabilistic modeling in order to capture the relationships between objectives and variables. This paper investigates the effects of joining the objective and variable information on the performance of an estimation of distribution algorithm for multi-objective optimization. A joint Gaussian Bayesian network of objectives and variables is learnt and then sampled using the information about currently best obtained objective values as evidence. The experimental results obtained on a set of multi-objective functions and in comparison to two other competitive algorithms are presented and discussed.

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# A Comparison of GEC-Based Feature Selection and Weighting for Multimodal Biometric Recognition

Alford, Aniesha Popplewell, Khary Dozier, Gerry Bryant, Kelvin Kelly, John Adams, Josh Abegaz, Tamirat Shelton, Joseph Ricanek, Karl Woodard, Damon L.

In this paper, we compare the performance of a Steady-State Genetic Algorithm (SSGA) and an Estimation of Distribution Algorithm (EDA) for multi-biometric feature selection and weighting. Our results show that when fusing face and periocular modalities, SSGA-based feature weighting (GEFeW(SSGA)) produces higher average recognition accuracies, while EDA-based feature selection (GEFeS(EDA)) performs better at reducing the number of features needed for recognition.

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# SSGA & EDA Based Feature Selection and Weighting for Face Recognition

Abegaz, Tamirat Dozier, Gerry Bryant, Kelvin Adams, Joshua Shelton, Joseph Ricanek, Karl Woodard, Damon L.

In this paper, we compare genetic and evolutionary feature selection (GEFeS) and weighting (GEFeW) using a number of biometric datasets. GEFeS and GEFeW have been implemented as instances of Steady-State Genetic and Estimation of Distribution Algorithms. Our results show that GEFeS and GEFeW dramatically improve recognition accuracy as well as reduce the number of features needed for facial recognition. Our results also show that the Estimation of Distribution Algorithm implementation of GEFeW has the best overall performance.

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# Training Multilayer Perceptrons with a Gaussian Artificial Immune System

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

In this paper we apply an immune-inspired approach to train Multilayer Perceptrons (MLPs) for classification problems. Our proposal, called Gaussian Artificial Immune System (GAIS), is an estimation of distribution algorithm that replaces the traditional mutation and cloning operators with a probabilistic model, more specifically a Gaussian network, representing the joint distribution of promising solutions. Subsequently, GAIS utilizes this probabilistic model for sampling new solutions. Thus, the algorithm takes into account the relationships among the variables of the problem, avoiding the disruption of already obtained high-quality partial solutions (building blocks). Besides the capability to identify and manipulate building blocks, the algorithm maintains diversity in the population, performs multimodal optimization and adjusts the size of the population automatically according to the problem. These attributes are generally absent from alternative algorithms, and all were shown to be useful attributes when optimizing the weights of MLPs, thus guiding to high-performance classifiers. GAIS was evaluated in six well-known classification problems and its performance compares favorably with that produced by contenders, such as opt-aiNet, IDEA and PSO.

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# Inductive Logic Programming Through Estimation of Distribution Algorithm

Pitangui, Cristiano Grijo Zaverucha, Gerson

Genetic Algorithms (GAs) are known for their capacity to explore large search spaces and due to this ability, they were to some extent applied to Inductive Logic Programming (ILP) problem. Although Estimation of Distribution Algorithms (EDAs) perform better in most problems when compared to standard GAs, this kind of algorithm have not been applied to ILP. This work presents an ILP system based on EDA. Preliminary results show that the proposed system is superior when compared to a "standard" GA and it is very competitive when compared to the state of the art ILP system Aleph.

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# Online Learning in Estimation of Distribution Algorithms for Dynamic Environments

Goncalves, Andre R. Von Zuben, Fernando J.

In this paper, we propose an estimation of distribution algorithm based on an inexpensive Gaussian mixture model with online learning, which will be employed in dynamic optimization. Here, the mixture model stores a vector of sufficient statistics of the best solutions, which is subsequently used to obtain the parameters of the Gaussian components. This approach is able to incorporate into the current mixture model potentially relevant information of the previous and current iterations. The online nature of the proposal is desirable in the context of dynamic optimization, where prompt reaction to new scenarios should be promoted. To analyze the performance of our proposal, a set of dynamic optimization problems in continuous domains was considered with distinct levels of complexity, and the obtained results were compared to the results produced by other existing algorithms in the dynamic optimization literature.

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# Handling Expensive Optimization with Large Noise

Coulom, Remi Rolet, Philippe Sokolovska, Nataliya Teytaud, Olivier

We present lower and upper bounds on runtimes for expensive noisy optimization problems. Runtimes are expressed in terms of number of fitness evaluations. Fitnesses considered are monotonic transformations of the sphere function. The analysis focuses on the common case of fitness functions quadratic in the distance to the optimum in the neighbourhood of this optimum it is nonetheless also valid for any monotonic polynomial of degree p &gt; 2. Upper bounds are derived via a bandit-based estimation of distribution algorithm that relies on Bernstein races called R-EDA. It is an evolutionary algorithm in the sense that it is based on selection, random mutations, with a distribution (updated at each iteration) for generating new individuals. It is known that the algorithm is consistent (i.e. it converges to the optimum asymptotically in the number of examples) even in some non-differentiable cases. Here we show that: (i) if the variance of the noise decreases to 0 around the optimum, it can perform well for quadratic transformations of the norm to the optimum, (ii) otherwise, a convergence rate is slower than the one exhibited empirically by an algorithm called Quadratic Logistic Regression (QLR) based on surrogate models-although QLR requires a probabilistic prior on the fitness class.

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# An improved quantum-behaved particle swarm optimization and its application to medical image registration

Zhou, Di Sun, Jun Lai, Choi-Hong Xu, Wenbo Lee, Xiaoguang

This paper investigates the quantum-behaved particle swarm optimization (QPSO) algorithm from the perspective of estimation of distribution algorithm (EDA) which reveals the reason of QPSO's superiority. A revised QPSO (RQPSO) technique with a novel iterative equation is also proposed. The modified technique is deduced from the distribution function of the sum of two random variables with exponential and normal distribution, respectively. We present a diversity-controlled RQPSO (DRQPSO) algorithm, which helps prevent the evolutionary algorithms' tendency to be easily trapped into local optima as a result of rapid decline in diversity. Both the RQPSO and DRQPSO are tested on three benchmark functions, as well as in medical image registration for performance comparison with the particle swarm optimization and QPSO.

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# Multi-population Coevolutionary Differential Evolution Algorithm

Zhang Yi Yang Xiuxia

The multi-population coevolutionary differential evolution (DE) based on estimation of distribution algorithm (EDA) is proposed. DE completes optimum search using the difference information between the individuals in the population, but the global population evolution information can not be used sufficiently. In this paper, the multi-population co-evolutionary is introduced, which incorporate the merits of the DE and EDA. The elite mutation is proposed in DE. To overcome the greed characteristic, the chaotic initialization and replacement are introduced in DE and the individual diversity in EDA is adjusted based on the individual density. Simulation results show the good global search ability of the proposed algorithm.

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# Two-stage EDA-based approach for all optical WDM mesh network survivability under SRLG constraints

Sun, Jianyong

In this paper, a two-stage evolutionary algorithm is proposed to solve an NP-complete telecommunication problem-all optical wavelength-division multiplexing (WDM) mesh network survivability under shared-risk-link-group (SRLG) constraints. First of all, a novel greedy heuristic with two control parameters is developed to construct feasible solutions of the telecommunication problem. An estimation of distribution algorithm (EDA) with guided mutation is applied to search for optimum settings of the two control parameters in respective two stages. Given the found best control parameters, an optimal solution of the considered problem can be constructed by the greedy heuristic. Experimental results show that the proposed approach compares favorably against the best-known evolutionary-based algorithm in 26 out of 30 test instances in terms of solution quality within given time limit. (c) 2010 Elsevier B. V. All rights reserved.

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