# Estimation of Distribution Algorithm with Local Sampling Strategy for Community Detection in Complex Networks

Yu, Fahong Li, Wenping He, Feng Yu, Bolin Xia, Xiaoyun Ma, Longhua

It is important to discover the potential community structure for analyzing complex networks. In this paper, an estimation of distribution algorithm with local sampling strategy for community detection in complex networks is presented to optimize the modularity density function. In the proposed algorithm, the evolution probability model is built according to eminent individuals selected by simulated annealing mechanism and a local sampling strategy based on a local similarity model is adopted to improve both the speed and the accuracy for detecting community structure in complex networks. At the same time, a more general version of the criterion function with a tunable parameter. lambda is used to avoid the resolution limit. Experiments on synthetic and real-life networks demonstrate the performance and the comparison of experimental results with those of several state-of-the-art methods, the proposed algorithm is considerably efficient and competitive.

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# MONEDA: scalable multi-objective optimization with a neural network-based estimation of distribution algorithm

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

The extension of estimation of distribution algorithms (EDAs) to the multi-objective domain has led to multi-objective optimization EDAs (MOEDAs). Most MOEDAs have limited themselves to porting single-objective EDAs to the multi-objective domain. Although MOEDAs have proved to be a valid approach, the last point is an obstacle to the achievement of a significant improvement regarding "standard" multi-objective optimization evolutionary algorithms. Adapting the model-building algorithm is one way to achieve a substantial advance. Most model-building schemes used so far by EDAs employ off-the-shelf machine learning methods. However, the model-building problem has particular requirements that those methods do not meet and even evade. The focus of this paper is on the model-building issue and how it has not been properly understood and addressed by most MOEDAs. We delve down into the roots of this matter and hypothesize about its causes. To gain a deeper understanding of the subject we propose a novel algorithm intended to overcome the drawbacks of current MOEDAs. This new algorithm is the multi-objective neural estimation of distribution algorithm (MONEDA). MONEDA uses a modified growing neural gas network for model-building (MB-GNG). MB-GNG is a custom-made clustering algorithm that meets the above demands. Thanks to its custom-made model-building algorithm, the preservation of elite individuals and its individual replacement scheme, MONEDA is capable of scalably solving continuous multi-objective optimization problems. It performs better than similar algorithms in terms of a set of quality indicators and computational resource requirements.

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# Evolutionary algorithms and elliptical copulas applied to Continuous optimization problems

de Mello Junior, Harold Dias Marti, Luis Abs da Cruz, Andre V. Rebuzzi Vellasco, Marley M. B.

Estimation of Distribution Algorithms (EDAs) constitutes a class of evolutionary algorithms that can extract and exploit knowledge acquired throughout the optimization process. The most critical step in the EDAs is the estimation of the joint probability distribution associated to the variables from the most promising solutions determined by the evaluation function. Recently, a new approach to EDAs has been developed, based on copula theory, to improve the estimation of the joint probability distribution function. However, most copula-based EDAs still present two major drawbacks: focus on copulas with constant parameters, and premature convergence. This paper presents a new copula-based estimation of distribution algorithm for numerical optimization problems, named EDA based on Multivariate Elliptical Copulas (EDA-MEC). This model,uses multivariate copulas to estimate the probability distribution for generating a population of individuals. The EDA-MEC differs from Other copula-based EDAs in several aspects: the copula parameter is dynamically estimated, using dependence measures; it uses a variation of the learned probability distribution to generate individuals that help to avoid premature convergence; and uses a heuristic to reinitialize the population as an additional technique to preserve the diversity of solutions. The paper shows, by means of a set of parametric tests, that this approach improves the overall performance of the optimization process when compared with other copula-based EDAs and with other efficient heuristics such as the Covariance Matrix Adaptation Evolution Strategy (CMA-ES). (C) 2016 Elsevier Inc. All rights reserved.

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# Data imputation for gas flow data in steel industry based on non-equal-length granules correlation coefficient

Lv, Zheng Zhao, Jun Liu, Ying Wang, Wei

In the field of data-driven based modeling and optimization, the completeness and the accuracy of data samples are the foundations for further research tasks. Since the byproduct gas system of steel industry is rather complicated and its data-acquisition process might be frequently affected by the unexpected operational factors, the data-missing phenomenon usually occurs, which might lead to the failure of model establishment or inaccurate information discovery. In this study, a data imputation method based on the manufacturing characteristics is proposed for resolving the data-missing problem in steel industry. A novel correlation analysis, named by non-equal-length granules correlation coefficient (NGCC), is reported, and the corresponding model based on Estimation of Distribution Algorithm (EDA) is established to study the correlation of the similar procedures. To verify the performance of the proposed method, this study considers three typical features of the gas flow data with different missing ratios. The experiment results indicate that it is greatly effective for the missing data imputation of byproduct gas, and exhibits better performance on the accuracy compared to the other methods. (C) 2016 Elsevier Inc. All rights reserved.

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# Performance of Estimation of distribution algorithm for initial core loading optimization of AHWR-LEU

Thakur, Amit Singh, Baltej Gupta, Anurag Duggal, Vibhuti Bhatt, Kislay Krishnani, P. D.

Population based evolutionary algorithms now form an integral part of fuel management in nuclear reactors and are frequently being used for fuel loading pattern optimization (LPO) problems. In this, paper we have applied Estimation of distribution algorithm (EDA) to optimize initial core loading pattern (LP) of AHWR-LEU. In EDA, new solutions are generated by sampling the probability distribution model estimated from the selected best candidate solutions. The weighing factor 'alpha' decides the fraction of current best solution for updating the probability distribution function after each generation. A wider use of EDA warrants a comprehensive study on parameters like population size, weighing factor 'alpha' and initial probability distribution function. In the present study, we have done an extensive analysis on these parameters (population size, weighing factor 'alpha' and initial probability distribution function) in EDA. It is observed that choosing a very small value of 'alpha' may limit the search of optimized solutions in the near vicinity of initial probability distribution function and better loading patterns which are away from initial distribution function may not be considered with due weightage. It is also observed that increasing the population size improves the optimized loading pattern, however the algorithm still fails if the initial distribution function is not close to the expected optimized solution. We have tried to find out the suitable values for 'alpha' and population size to be considered for AHWR-LEU initial core loading pattern optimization problem. For sake of comparison and completeness, we have also addressed the initial core optimization of AHWR-LEU by using Genetic algorithm (GA). In GA too, similar dependence on population size and initial distribution function is observed. However, by increasing the population size, the results in GA optimization improved drastically. (C) 2016 Elsevier Ltd. All rights reserved.

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# A Hybrid Territory Defined evolutionary algorithm approach for closed loop green supply chain network design

Tiwari, Anurag Chang, Pei-Chann Tiwari, M. K. Kandhway, Rishabh

The Closed loop Supply chain network distribution is one of the most important problems with much real world application in supply chain management area. Presently climate change problem is one of the major concerns for Researchers. Closed loop green supply chain (GCLSC) problem is the extension of closed loop supply chain problem. Semiconductor industries are one of the major industries and a number of waste products in semiconductor industries are quite high. We have considered reducing the waste in semiconductor by recycling the useful waste electronic equipment. In GCLSC, we consider to maximize the profit in forward supply chain whereas we attempt to minimize the Carbon footprints at the same time. In this paper we used a hybrid of Estimation of distribution algorithm (EDA) and Territory Defined multi-objective algorithm to select the optimum number of facilities in the closed loop supply chain network. To examine the effectiveness of our Hybrid Territory Defined algorithm (EDATDEA), we compare the results with those obtained by NSGA II on a same GCLSC problem with different problem sizes and the same data sets. (C) 2016 Elsevier Ltd. All rights reserved.

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# Estimation of Distribution Algorithm for Energy-Efficient Scheduling in Turning Processes

Wang, Fang Rao, Yunqing Zhang, Chaoyong Tang, Qiuhua Zhang, Liping

With the increasing concern for the environment, energy-efficient scheduling of the manufacturing industry is becoming urgent and popular. In turning processes, both spindle speed and processing time affect the final energy consumption and thus the spindle speed and scheduling scheme need to be optimized simultaneously. Since the turning workshop can be regarded as the flexible flow shop, this paper formulates a mixed integer nonlinear programming model for the energy-efficient scheduling of the flexible flow shop. Accordingly, a new decoding method is developed for the optimization of both spindle speed and scheduling scheme simultaneously, and an estimation of the distribution algorithm adopting the new decoding method is proposed to solve large-size problems. The parameters of this algorithm are determined by statistics from a simplified practical case. Validation results of the proposed method show that the makespan is shortened to a large extent, and the consumed energy is significantly saved. These results demonstrate the effectiveness of the proposed mathematical model and algorithm.

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# Simulation optimization for the vehicle routing problem with time windows using a Bayesian network as a probability model

Perez-Rodriguez, Ricardo Hernandez-Aguirre, Arturo

The main purpose of the vehicle routing problem (VRP) is to deliver a set of customers with known demands on minimum-travel routes and terminating at the same depot. The vehicle routing problem with time windows (VRPTW) requires the delivery made in a specific time window for every customer and returning to the depot before a due time. Contrary to current research, an estimation of distribution-algorithm-based approach coupled with a simulation model is proposed and developed to solve the problem and implement the solution. The approach mentioned makes use of a Bayesian network as a probability model to describe the distribution of the solution space. Furthermore, the approach taken in this study combines the key advantages of both estimation of distribution algorithms (EDA) and simulation. The simulation is used to model the VRPTW environment, while the EDA is used to guide the overall search process to identify the best performing ones. Solomon's (Oper Res 35:254-265, 1987) instances served as input and test parameters in order to show that there exists a relationship and interaction between vertices and positions on the sequence of the VRPTW solution. A better position for each vertex on the sequence can be estimated through a Bayesian network. Experimental results show that the EDA performance was better in 70 % of the cases, as average, for the number of vehicles used in all the trails with respect the other algorithms proposed as a benchmark for comparison with the EDA scheme.

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# A Hybrid Estimation of Distribution Algorithm for Unrelated Parallel Machine Scheduling with Sequence-Dependent Setup Times

Wang, Ling Wang, Shengyao Zheng, Xiaolong

Abstract no encontrado

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# MARLEDA: Effective distribution estimation through Markov random fields

Alden, Matthew Miikkulainen, Risto

Estimation of Distribution Algorithms (EDAs) combine genetic algorithms with statistical modeling in order to learn and exploit the structure of search domains. Such algorithms work well when the EDA's statistical model matches the structure of the domain. Many EDAs use statistical models that represent domain structure with directed acyclic graphs (DAGs). While useful in many areas, DAGs have inherent restrictions that make undirected graph models a viable alternative for many domains. This paper introduces a new EDA, the Markovian Learning Estimation of Distribution Algorithm (MARLEDA), that makes effective use of this idea by employing a Markov random field model. MARLEDA is evaluated on four combinatorial optimization tasks, OneMax, deceptive trap functions, the 2D Rosenbrock function, and 2D Ising spin glasses. MARLEDA is shown to perform better than standard genetic algorithms and a DAG-based EDA. Improving the modeling capabilities of EDAs in this manner brings them closer to effective applications in difficult real-world domains, such as computational biology and autonomous agent design. (C) 2015 Elsevier B.V. All rights reserved.

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# Immune Algorithm Combined with Estimation of Distribution for Traveling Salesman Problem

Xu, Zhe Wang, Yirui Li, Sheng Liu, Yanting Todo, Yuki Gao, Shangce

This paper describes an artificial immune algorithm (IA) combined with estimation of distribution algorithm (EDA), named IA-EDA, for the traveling salesman problem (TSP). Two components are incorporated in IA-EDA to further improve the performance of the conventional IA. First, aiming to strengthen the information exchange during different solutions, two kinds of EDAs involving univariate marginal distribution algorithm and population-based incremental learning are altered based on the permutation representation of TSP. It is expected that new promising candidate solutions can be sampled from the constructed probabilistic model of EDA. Second, a heuristic refinement local search operator is proposed to repair the infeasible solutions sampled by EDA. Therefore, IA-EDA can alleviate the deficiencies of the conventional IA and can find better solutions for TSP by well balancing the exploitation and exploration of the search. Experiments are conducted based on a number of benchmark instances with size up to 100 000 cities. Simulation results show that IA-EDA is effective for improving the performance of the conventional IA and can produce better or competitive solutions than other hybrid algorithms. (C) 2016 Institute of Electrical Engineers of Japan. Published by John Wiley &amp; Sons, Inc.

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# Sequence searching and evaluation: a unified approach for aircraft arrival sequencing and scheduling problems

Ji, Xiao-Peng Cao, Xian-Bin Tang, Ke

Arrival sequencing and scheduling (ASS) is an important part of air traffic control. In the literature, various formulations of the ASS problems have been established by taking different scheduling requirements into account, and various methods have been developed to cope with these ASS problems. However, it is usually uneasy to generalize a method designed for one ASS formulation to another, while an approach that is able to handle different ASS problems is of great significance since air traffic controllers may need to switch among different scheduling requirements in practice. Motivated by this observation, an approach that is applicable to a number of different problem formulations of ASS is proposed in this paper. Specifically, the ASS problems that include different objective functions and constraints are firstly abstracted as a constrained permutation-based problem. After that, a Sequence Searching and Evaluation (SSE) approach is developed for the constrained permutation-based problem. The SSE solves different ASS problems by separating the sequence searching in one stage using an Estimation of Distribution Algorithm framework, and evaluating sequences in the second stage. Experiment results show that SSE is capable of obtaining competitive solutions for a variety of ASS problems.

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# Evaluation of Estimation of Distribution Algorithm to Calibrate Computationally Intensive Hydrologic Model

Li, Zejun Liu, Pan Deng, Chao Guo, Shenglian He, Ping Wang, Caijun

The estimation of distribution algorithm(EDA) is a new evolutionary algorithm developed as an alternative to the traditional genetic algorithm (GA). The EDA guides the search by avoiding the crossover and mutation operators of the GA in favor of building and sampling probabilistic distributions of promising candidate solutions. By increasing the probability of generating solutions with better fitness values, the EDA locates the region of the global optimum or its accurate approximation. In this study, EDA was used to calibrate the parameters of the soil and water assessment tool hydrologic model for the Xunhe River Basin in China. The EDA was compared with three other algorithms: (1) the Multistart Local Metric Stochastic Radial Basis Function algorithm (a surrogate optimization method), (2) the Shuffled Complex Evolution algorithm, and (3) the GA. Four metrics are presented to assess the performance of the algorithms: (1) efficiency in terms of the average best objective function value in a limited number of function evaluations, (2) variability in terms of standard deviation and the box plot, (3) reliability in terms of the empirical cumulative distribution function, and (4) accuracy in terms of the Nash-Sutcliffe efficiency coefficient and overall volume error. Results indicated that the EDA is more efficient and could provide more accurate solutions with a relatively high probability, at least for this case study. (C) 2016 American Society of Civil Engineers.

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# Design and optimization of HIDiC columns using a constrained Boltzmann-based estimation of distribution algorithm-evaluating the effect of relative volatility

Gutierrez-Guerra, Roberto Murrieta-Duenas, Rodolfo Cortez-Gonzalez, Jazmin Gabriel Segovia-Hernandez, Juan Hernandez, Salvador Hernandez-Aguirre, Arturo

In this paper we study the design and optimization of heat-integrated distillation columns (HIDiC) using a constrained Boltzmann-based estimation of distribution algorithm. The total annual cost was defined as the fitness function of the problem, and the effect of the relative volatility on the performance of the HIDiC configurations was evaluated.

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# A multi-cycled sequential memetic computing approach for constrained optimisation

Sun, Jianyong Garibaldi, Jonathan M. Zhang, Yongquan Al-Shawabkeh, Abdallah

In this paper, we propose a multi-cycled sequential memetic computing structure for constrained optimisation. The structure is composed of multiple evolutionary cycles. At each cycle, an evolutionary algorithm is considered as an operator, and connects with a local optimiser. This structure enables the learning of useful knowledge from previous cycles and the transfer of the knowledge to facilitate search in latter cycles. Specifically, we propose to apply an estimation of distribution algorithm (EDA) to explore the search space until convergence at each cycle. A local optimiser, called DONLP2, is then applied to improve the best solution found by the EDA. New cycle starts after the local improvement if the computation budget has not been exceeded. In the developed EDA, an adaptive fully-factorized multivariate probability model is proposed. A learning mechanism, implemented as the guided mutation operator, is adopted to learn useful knowledge from previous cycles.

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# Structure-control design of a mechatronic system with parallelogram mechanism using an estimation of distribution algorithm

Ivvan Valdez, S. Chavez-Conde, E. Hernandez, Eusebio E. Ceccarelli, M.

In this paper, a structure-control design methodology for simultaneously optimizing both mechanical structure and control of a parallelogram linkage robot is proposed. It takes into count the dynamical model and the mechanical parameters for the optimization process along with the controller. Thus, proportional-integral-derivative (PID) control and geometric variables are optimized in a simultaneously way. Through the concurrent procedure an optimal combination of the robot structure and controller gains is obtained. The global optimization problem is tackled by using an estimation of distribution algorithm (EDA) based on the Boltzmann distribution. The EDA seeks for the global optimum by estimating and sampling a probability distribution. The proposed methodology is verified through simulation experiments and applied to the design process of a parallelogram linkage system. The results obtained in experiments show the effectiveness of the proposal. This approach is generic and could be applied to other mechanisms in similar way when for concurrent process both kinematic and dynamic models are available along with the controller. In particular, the results are promising when the optimization parameters are uncorrelated, namely control and mechanical parameters.

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# Estimation of distribution algorithm enhanced particle swarm optimization for water distribution network optimization

Qi, Xuewei Li, Ke Potter, Walter D.

The optimization of a water distribution network (WDN) is a highly nonlinear, multi-modal, and constrained combinatorial problem. Particle swarm optimization (PSO) has been shown to be a fast converging algorithm for WDN optimization. An improved estimation of distribution algorithm (EDA) using historic best positions to construct a sample space is hybridized with PSO both in sequential and in parallel to improve population diversity control and avoid premature convergence. Two water distribution network benchmark examples from the literature are adopted to evaluate the performance of the proposed hybrid algorithms. The experimental results indicate that the proposed algorithms achieved the literature record minimum (6.081 M$) for the small size Hanoi network. For the large size Balerma network, the parallel hybrid achieved a slightly lower minimum (1.921Ma,not sign) than the current literature reported best minimum (1.923Ma,not sign). The average number of evaluations needed to achieve the minimum is one order smaller than most existing algorithms. With a fixed, small number of evaluations, the sequential hybrid outperforms the parallel hybrid showing its capability for fast convergence. The fitness and diversity of the populations were tracked for the proposed algorithms. The track record suggests that constructing an EDA sample space with historic best positions can improve diversity control significantly. Parallel hybridization also helps to improve diversity control yet its effect is relatively less significant.

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# C-Multi: A competent multi-swarm approach for many-objective problems

Castro, Olacir R., Jr. Santana, Roberto Pozo, Aurora

One of the major research topics in the evolutionary multi-objective community is handling a large number of objectives also known as many-objective optimization problems (MaOPs). Most existing methodologies have demonstrated success for problems with two and three objectives but face significant challenges in many-objective optimization. To tackle these challenges, a hybrid multi-swarm algorithm called C-Multi was proposed in a previous work. The project of C-Multi is based on two phases; the first uses a unique particle swarm optimization (PSO) algorithm to discover different regions of the Pareto front. The second phase uses multiple swarms to specialize on a dedicate part. On each sub swarm, an estimation of distribution algorithm (EDA) is used to focus on convergence to its allocated region. In this study, the influence of two critical components of C-Multi, the archiving method and the number of swarms, is investigated by empirical analysis. As a result of this investigation, an improved variant of C-Multi is obtained, and its performance is compared to I-Multi, a multi-swarm algorithm that has a similar approach but does not use EDAs. Empirical results fully demonstrate the superiority of our proposed method on almost all considered test instances. (C) 2015 Elsevier B.V. All rights reserved.

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# The use of explicit building blocks in evolutionary computation

Sangkavichitr, Chalermsub Chongstitvatana, Prabhas

This paper proposes a new algorithm to identify and compose building blocks. Building blocks are interpreted as common subsequences between good individuals. The proposed algorithm can extract building blocks from a population explicitly. Explicit building blocks are identified from shared alleles among multiple chromosomes. These building blocks are stored in an archive. They are recombined to generate offspring. The additively decomposable problems and hierarchical decomposable problems are used to validate the algorithm. The results are compared with the Bayesian optimisation algorithm, the hierarchical Bayesian optimisation algorithm, and the chi-square matrix. This proposed algorithm is simple, effective, and fast. The experimental results confirm that building block identification is an important process that guides the recombination procedure to improve the solutions. In addition, the method efficiently solves hard problems.

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# Recursion-Based Biases in Stochastic Grammar Model Genetic Programming

Kim, Kangil Mckay, R. I. (Bob) Nguyen Xuan Hoai

The estimation of distribution algorithms (EDAs) applied to genetic programming (GP) have been studied by a number of authors. Like all EDAs, they suffer from biases induced by the model building and sampling process. However, the biases are amplified in the algorithms for GP. In particular, many systems use stochastic grammars as their model representation, but biases arise due to grammar recursion. We define and estimate the bias due to recursion in grammar-based EDAs in GP, using methods derived from computational linguistics. We confirm the extent of bias in some simple experimental examples. We then propose some methods to repair this bias. We apply the estimation of bias, and its repair, to some more practical applications. We experimentally demonstrate the extent of bias arising from recursion, and the performance improvements that can result from correcting it.

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# Estimation of the Distribution Algorithm With a Stochastic Local Search for Uncertain Capacitated Arc Routing Problems

Wang, Juan Tang, Ke Lozano, Jose A. Yao, Xin

The uncertain capacitated arc routing problem is a challenging problem in which the demands of tasks, the costs of edges, and the presence of tasks and edges are uncertain. The objective of this problem is to find a robust optimal solution for a finite set of possible scenarios. In this paper, we propose a novel robust optimization approach, called an estimation of distribution algorithm (EDA) with stochastic local search (SLS), to tackle this problem. The proposed method integrates an EDA with a novel two phase SLS procedure to minimize the maximal total cost over a set of different scenarios. The SLS procedure avoids excessive fitness evaluations of unpromising moves in local search. Our experimental results on two sets of benchmark problems (a total of 55 problem instances) showed that the proposed approach outperformed existing state-of-the-art algorithms.

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# Path Planning of Aircraft Based on Adaptive Multiobjective Estimation of Distribution Algorithm

Lin, Tao Zhang, Ke Cui, Naigang Tu, Zhenbiao Zhang, Hu

Path planning is able to effectively improve the survival probability and operational efficiency of a combat aircraft. The essence of path planning of the aircraft is a multiobjective optimization problem. To deal with this problem efficiently, this paper proposes an adaptive multiobjective estimation of distribution algorithm named as AMEDA. In AMEDA, a novel clustering-based multivariate Gaussian sampling strategy is designed. At each generation, a clustering analysis approach is utilized to discover the distribution structure of the population. Based on the distribution information, with a certain probability, a local or a global multivariate Gaussian model (MGM) is built for each solution to sample a new solution. A covariance sharing strategy is designed in AMEDA to reduce the complexity of building MGMs, and an adaptive update strategy of the probability that controls the contributions of the two types of MGMs is developed to dynamically balance exploration and exploitation. Experiments show that AMEDA is efficient to deal with the path planning model of the aircraft. Meanwhile, it is convenient to provide multiple flight paths with different characteristics for the decision makers.

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# A Hybrid Estimation of Distribution Algorithm with Differential Evolution for Global Optimization

Dong, Bing Zhou, Aimin Zhang, Guixu

In evolutionary algorithms, it is difficult to balance the exploration and exploitation. Usually, global search is utilized to find promising solutions, and local search is beneficial to the convergence of the solutions in the population. Combing different search strategies is a promising way to take advantages of different methods. Following the idea of DE/EDA, this paper proposes another way to combine estimation of distribution algorithm and differential evolution for global optimization. The basic idea is to choose either differential evolution or estimation of distribution algorithm for generating new trial solutions. To improve the algorithm performance, a local search strategy is used as well. The new approach, named as EDA/DE-EIG, is systematically compared with two state-of-art algorithms, and the experimental results show the advantages of our method.

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# An Augmented Estimation of Distribution Algorithm For Multi-Carpooling Problem With Time Window

Zhang, Fang Yang, Z. J. Wang, Y. Kuang, Fangjun

A multi-carpooling model is proposed for the multi-vehicle carpooling problem in distributed parallel computing environment. A two-stage stochastic optimization of the estimation of distribution algorithm solves the optimum of the multi-carpooling problem with a carpooling probabilistic matrix. A ridable matrix initiates the carpooling probabilistic matrix, and the carpooling probabilistic matrix continues updating during the optimization. The carpooling model mines efficient and compromised ridesharing routes for shared riders by the optimization iterations. Experimental results indicate that the carpooling model has the characteristics of effective and efficient traffic including shorter waiting time, more passenger load, and less average riding distance.

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# Concurrent design optimization of the Delta manipulator

Botello-Aceves, Salvador Ivvan Valdez, S. Becerra, Hector M.

The problem of concurrent design of a mechanism can be defined as finding optimal structural parameters and control parameters for a given objective function during the same optimization process. In this paper, a general concurrent optimization methodology for kinematically complex mechanisms is tested using a Delta manipulator. This methodology intends to optimize any structure and control design, using any specified kinematic or dynamic models. Thus, general optimization methods not dependent on mathematical characteristics of the objective function are used. The main contribution of this work is to define, develop and test a general methodology that can generate optimal designs based on workspace and task requirements, such that they guarantee an adequate performance under a set of operating and joint constraints. We test three families of evolutionary algorithms: a genetic algorithm, an evolution strategy and an estimation of distribution algorithm, for two objective functions. The reported results give directions about the most adequate method to tackle the concurrent design problem.

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# MICPSO: A Method for Incorporating Dependencies into Discrete Particle Swarm Optimization

Goodman, Rollie Thornton, Monica Strasser, Shane Sheppard, John W.

In this work, we present an extension to the recently developed Integer and Categorical Particle Swarm Optimization (ICPSO), which we refer to as Markovian ICPSO (MICPSO). MICPSO uses a Markov network to represent a particle's position, thus allowing each particle to incorporate information about dependencies between solution variables. In this work, we compare MICPSO to ICPSO, Integer PSO (IPSO), an Estimation of Distribution Algorithm called Markovianity-Based Optimization Algorithm (MOA), and a hillclimber on a set of benchmark vertex coloring problems. We find that MICPSO significantly outperforms all alternatives on all problems tested.

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# Camera Self-Calibration from Tracking of Moving Persons

Tang, Zheng Lin, Yen-Shuo Lee, Kuan-Hui Hwang, Jenq-Neng Chuang, Jen-Hui Fang, Zhijun

In a video surveillance system with a single static camera, tracking results of moving persons can be effectively used for camera self-calibration. However, the current methods need to depend on robustness of both tracking and segmentation procedures. RANSAC has been widely used to remove outliers in finding the vertical vanishing point and the horizon line, but the performance is degraded when the proportion of outliers is high. Last but not least, all of them require excessive simplifications in the algorithmic procedures resulting in increasing reprojection error. In this paper, a robust segmentation and tracking system is applied to provide accurate estimation of head and foot locations of moving persons. The noise in the computation of vanishing points is handled by mean shift clustering and Laplace linear regression through convex optimization. We also propose to use the estimation of distribution algorithm (EDA) to search for the local optimal solution for camera calibration that minimizes average reprojection error on the ground plane, while relaxing the assumptions on camera parameters. Promising evaluations of the performance of our proposed method on real scenes are presented.

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# EDA-based Decomposition Approach for Binary LSGO Problems

Sopov, Evgenii

In recent years many real-world optimization problems have had to deal with growing dimensionality. Optimization problems with many hundreds or thousands of variables are called large-scale global optimization (LSGO) problems. Many well-known real-world LSGO problems are not separable and are complex for detailed analysis, thus they are viewed as the black-box optimization problems. The most advanced algorithms for LSGO are based on cooperative coevolution schemes using the problem decomposition. These algorithms are mainly proposed for the real-valued search space and cannot be applied for problems with discrete or mixed variables. In this paper a novel technique is proposed, that uses a binary genetic algorithm as the core technique. The estimation of distribution algorithm (EDA) is used for collecting statistical data based on the past search experience to provide the problem decomposition by fixing genes in chromosomes. Such an EDA-based decomposition technique has the benefits of the random grouping methods and the dynamic learning methods. The EDA-based decomposition GA using the island model is also discussed. The results of numerical experiments for benchmark problems from the CEC competition are presented and discussed. The experiments show that the approach demonstrates efficiency comparable to other advanced techniques.

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# CFO: A New Compact Swarm Intelligent Algorithm for Global Optimization and Optimal Bipedal Robots Walking

Tighzert, Lycs Mendil, Boubekeur

this paper introduces compact swarm intelligence. It presents a new estimation of distribution algorithm based on the swarm behavior of fireflies. The proposed algorithm is called the compact firefly optimizer (cFO). It uses a compact representation to store the population of the fireflies. Thus, the whole population is represented by a probabilistic distribution function. The compact swarm intelligence proposed allows the reduction of the computational capacity required to evolve the population toward the optimal solution. An important numerical test is used to evaluate the performance of the proposed algorithm. The results obtained show that the proposed compact firefly optimizer (cFO) is very competitive. Furthermore, the new concepts of compact swarm robotics are also introduced. The algorithm is applied to describe the first compact swarm robotics system. The objective is to realize an optimal stable walking by bipedal robot. Discussions, propositions and analysis let to think to a new important starting point for an emerging field of compact swarm intelligence, robotics, search and optimization.

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# Multi-objective Estimation of Distribution algorithm based on Voronoi and Local search

Mohagheghi, Elham Akbarzadeh-T, Mohammad-R.

In this paper we propose an Estimation of Distribution Algorithm (EDA) equipped with Voronoi and local search based on leader for multi-objective optimization. We introduce an algorithm that can keep the balance between the exploration and exploitation using the local information in the searched areas through the global estimation of distribution algorithm. Moreover, the probability model in EDA, receives special statistical information about the amount of the variables and their important dependency. The proposed algorithm uses the Voronoi diagram in order to produce the probability model. By using this model, there will be a selection based on the area instead of selection based on the individual, and all individual information could use to produce new solution. In the proposed algorithm, considering the simultaneous use of global information about search area, local information of the solutions and the Voronoi based probability model lead to produce more diverse solutions and prevent sticking in local optima. Also, in order to reduce the data dimension, the principle component analysis is proposed. Several benchmarks functions with different complexity like linear and non-linear relationship between the variables, the continues\discontinues and convex\non-convex optima fronts use to show the algorithm performance.

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# Cloud estimation of distribution algorithm with quasi-oppositional learning and preference order ranking for multi-objective optimisation

Gao, Ying Liu, Waixi

Abstract no encontrado

[Paper](https://www.webofscience.com/api/gateway?GWVersion=2&SrcApp=edas&SrcAuth=WosAPI&KeyUT=WOS:000389904600005&DestLinkType=FullRecord&DestApp=WOS_CPL)

# An Operation Optimization Method Based on Improved EDA for BOF End-point Control

Liu, Chang Song, Xiangman Xu, Te Tang, Lixin

Due to the large amounts of energy consumption in the converter steelmaking production process, the furnace state generates a fierce chemical reaction, and accompanies with high temperature. In this paper, in order to accurately control and optimize the converter steelmaking production process, and guarantee the quality of products, the data analytics method based on least square support vector machine (LSSVM) is used to establish the operation optimization model of converter steelmaking. Meanwhile, a kind of operation optimization method based on improved estimation of distribution algorithm (IEDA) is proposed, and Gaussian model is selected as the probabilistic model. In order to increase the diversity of population, the variable scale variance strategy is developed. In addition, aiming at the local search ability, the mutation mechanism of modified differential evolution algorithm is adopted in the search process. The experimental results illustrate that the proposed method can effectively solve the end-point control problems of temperature and carbon content in BOF steelmaking process.

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# SMS-EDA-MEC: Extending Copula-based EDAs to Multi-Objective Optimization

Marti, Luis de Mello, Harold D., Jr. Sanchez-Pi, Nayat Vellasco, Marley

It can be argued that in order to produce a substantial improvement in multi-objective estimation of distribution algorithms it is necessary to focus on a particular group of issues, in particular, on the weaknesses derived from multi-objective fitness assignment and selection methods, the incorrect treatment of relevant but isolated (precursor) individuals; the loss of population diversity, and the use of 'general purpose' modeling algorithms without taking note of the particular requirements of the task. In this work we introduce the S-Metric Selection Estimation of Distribution Algorithm based on Multivariate Extension of Copulas (SMS-EDA-MEC). SMS-EDA-MEC was devised with the intention of dealing with those issues in mind. It builds the population model relying on the comprehensive Clayton's copula and incorporates methods for automatic population restarting and for priming precursor individuals. The experimental studies presented show that SMS-EDA-MEC yields better results than current and 'traditional' approaches.

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# A Hybrid Estimation of Distribution Algorithm for Distributed Permutation Flowshop Scheduling with Flowline Eligibility

Duan, Wenzhe Li, Zhengyang Ji, Mengchen Yang, Yixin Tang, Shouyang Liu, Bo

This paper studies a new extension of distributed permutation flow shop scheduling problem (DPFSP) referred to as the DPFSP with flowline eligibility. Under this extension, the problem contains two stages. At the first assignment stage, a set N of n jobs is distributed among F factories with flowline eligibility constraint, i.e., not all the factories are available for every job. Then each factory can be regarded as a regular permutation flow shop scheduling problem (PFSP) in which jobs assigned to each factory have to be processed on m machines according to the given permutation. The objective is to minimize the maximum completion time or makespan of all the factories. The flowline eligibility constraint adds asymmetry and complexity to the regular DPFSP. In the proposed hybrid estimation of distribution algorithm (hybrid EDA), a heuristic of Framinan and Leisten (FLH) based solution-generate method (FLHSGM), two novel factory-based operators are proposed, and an effective local search based on variable neighborhood search (VNS) is employed and incorporated into EDA. Numerical simulations with comprehensive computational and statistical analysis are carried out. The experimental results and comparisons with existing algorithms show that the FLHSGM and the VNS-based local search enhances the search ability of EDA and the effectiveness of the hybrid EDA in solving both small-scale and large-scale DPFSP with flowline eligibility.

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# An Estimation of Distribution Algorithm Guided by Mean Shift

Fang, Hui Zhou, Aimin Zhang, Guixu

The estimation of distribution algorithm is widely used to solve global optimization problems in recent years. The basic idea is using machine learning methods to extract relevant features of the search space among the selected individuals and to construct a probabilistic model for sampling new solutions. As we know, EDAs mainly focus on the global distribution information of population and are lack of solution location information. In this paper, we extend our previous work to propose a new EDA guided by the mean shift method, which is originally proposed as a density estimation method and is used as a local search method in this paper. In the new approach, at first a set of candidate solutions are generated by EDA. Then the mean shift method is used to refine some good parent solutions. Finally the sampled candidate solutions and the refined solutions are combined to form the offspring solutions. By this way, the global distribution information and the solution location information are used in offspring reproduction. We apply the new approach to a set of test instances and the experiment results indicate that the new algorithm can obtain good performance in most functions with a faster convergence rate.

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# Sampling in Latent Space for a Mulitiobjective Estimation of Distribution Algorithm

Dong, Bing Zhou, Aimin Zhang, Guixu

A regularity model-based multiobjective estimation of distribution algorithm (RM-MEDA) has been proposed for continuous multiobjective optimization problems. Generating promising solutions to approximate the population is significant to RM-MEDA. In the reproduction of RM-MEDA, it adopts a Latin square design strategy to sample points in the latent space that is extended to cover the whole Pareto set. However, the setting of the extension scale is problem-dependent to some extent. To circumvent this issue, we propose a differential evolution based sampling (DES) scheme for RM-MEDA. DES mutates the projections of the parent solutions in the latent space to generate promising candidate offspring solutions. The empirical experiment results have shown the significant advantages of the DES scheme comparing to the Latin square design.

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# BPGA-EDA for the Multi-Mode Resource Constrained Project Scheduling Problem

Ayodele, Mayowa McCall, John Regnier-Coudert, Olivier

The Multi-mode Resource Constrained Project Scheduling Problem (MRCPSP) has been of research interest for over two decades. The problem is composed of two interacting sub problems: mode assignment and activity scheduling. These problems cannot be solved in isolation because of the interaction that exists between them. Many evolutionary algorithms have been applied to this problem most commonly the Genetic Algorithm (GA). It has been common practice to improve the performance of the GA with some local search techniques. The Bi-population Genetic Algorithm (BPGA) is one of the most competitive GAs for solving the MRCPSP. In this paper, we improve the BPGA by hybridising it with an Estimation of Distribution Algorithm that focuses on improving how modes are generated. We also suggest improvement to the existing experimental methodology.

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# An Effective Estimation of Distribution Algorithm for Solving Uniform Parallel Machine Scheduling Problem with Precedence Constraints

Wu, Chu-ge Wang, Ling Zheng, Xiao-long

In this paper, an effective estimation of distributed algorithm (eEDA) is proposed to solve the uniform parallel machine scheduling problem with precedence constraints (prec-UFPMSP). In the eEDA, the permutation-based encoding scheme is adopted and the earliest finish time (EFT) method is used to decode the solutions to the detail schedules. A new effective probability model is designed to describe the relative positions of the jobs. Based on such a model, an incremental learning based updating method is developed and a sampling mechanism is proposed to generate feasible solutions with good diversity. In addition, the Taguchi method of design-of-experiment (DOE) method is used to investigate the effect of key parameters on the performance of the eEDA. Finally, numerical tests are carried out to demonstrate the superiority of the probability model, and the comparative results show that the eEDA outperforms the existing algorithm for most cases.

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# An Effective DE-EDA for Permutation Flow-shop Scheduling Problem

Li, Zuo-cheng Guo, Qingxin Tang, Lixin

Aiming at the permutation flow-shop scheduling problem (PFSSP) with makespan criterion, a combination algorithm based on differential evolution (DE) and estimation of distribution algorithm (EDA), namely DE-EDA, is proposed. Firstly, DE-EDA combines the probability-dependent macro information extracted by EDA and the individual-dependent micro information obtained by DE to execute the exploration, which is helpful in guiding the global search to explore promising solutions. Secondly, in order to make DE well suited to solve PFSSP, a convert rule named smallest-ranked-value (SRV) is designed to generate the discrete job permutations from the continuous values. Thirdly, a sequence-learning-based Bayes posterior probability is presented to estimate EDA's probability model and sample new solutions, so that the global information of promising search regions can be learned precisely. In addition, a simple but effective two-stage local search is embedded into DE-EDA to perform the exploitation, and thereafter numerous potential solution(s) with relative better fitness can be exploited in some narrow search regions. Finally, simulation experiments and comparisons based on 29 well-known benchmark instances demonstrate the effectiveness of the proposed DE-EDA.

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# Enhance Continuous Estimation of Distribution Algorithm by Variance Enlargement and Reflecting Sampling

Ren, Zhigang He, Chenlong Zhong, Dexing Huang, Shanshan Liang, Yongsheng

Estimation of distribution algorithm (EDA) is a kind of typical model-based evolutionary algorithm (EA). Although possessing competitive advantages in theoretical analysis, current EDAs may encounter premature convergence due to the rapid shrinkage of the search range and the relatively low sampling efficiency. Focusing on continuous EDAs with Gaussian models, this paper proposes a novel probability density estimator which can adaptively enlarge the variances and thus endow EDA with flexible search behavior. For the estimated probability density, a reflecting sampling strategy which can further improve the search efficiency is put forward. With these two algorithmic strategies, a new EDA variant named EDA(ve-rs) is developed. Experimental results on a set of benchmark problems demonstrate that EDA(ve-rs) outperforms conventional EDAs and can produce superior solutions in comparison with some state-oft-he-art EAs.

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# Development of a time-dependent economic method with start time consideration to optimise gas-lift allocation and scheduling

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

The gas lift allocation optimisation is an important operational problem. In this paper, we present a method to optimise the lift gas allocation profile and determine the best time to start the gas-lift operation for each well. To tackle the nonlinear optimisation, an estimation of distribution algorithm (EDA) is employed based on Gaussian Bayesian networks and Gaussian kernels and the results are compared with those obtained by particle swarm optimisation (PSO) and genetic algorithms (GAs). Gas-lift performance for all the wells along with estimated cumulative production data are correlated over time to develop a model to show the field production behaviour as a function of the gas injection rates and initiation parameters. The developed model is coupled with an economic model to maximise the net present value of the gas-lift process for the field.

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# REMEDA: Random Embedding EDA for Optimising Functions with Intrinsic Dimension

Sanyang, Momodou L. Kaban, Ata

It has been observed that in many real-world large scale problems only few variables have a major impact on the function value: While there are many inputs to the function, there are just few degrees of freedom. We refer to such functions as having a low intrinsic dimension. In this paper we devise an Estimation of Distribution Algorithm (EDA) for continuous optimisation that exploits intrinsic dimension without knowing the influential subspace of the input space, or its dimension, by employing the idea of random embedding. While the idea is applicable to any optimiser, EDA is known to be remarkably successful in low dimensional problems but prone to the curse of dimensionality in larger problems because its model building step requires large population sizes. Our method, Random Embedding in Estimation of Distribution Algorithm (REMEDA) remedies this weakness and is able to optimise very large dimensional problems as long as their intrinsic dimension is low.

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# RK-EDA: A Novel Random Key Based Estimation of Distribution Algorithm

Ayodele, Mayowa McCall, John Regnier-Coudert, Olivier

The challenges of solving problems naturally represented as permutations by Estimation of Distribution Algorithms (EDAs) have been a recent focus of interest in the evolutionary computation community. One of the most common alternative representations for permutation based problems is the Random Key (RK), which enables the use of continuous approaches for this problem domain. However, the use of RK in EDAs have not produced competitive results to date and more recent research on permutation based EDAs have focused on creating superior algorithms with specially adapted representations. In this paper, we present RK-EDA; a novel RK based EDA that uses a cooling scheme to balance the exploration and exploitation of a search space by controlling the variance in its probabilistic model. Unlike the general performance of RK based EDAs, RK-EDA is actually competitive with the best EDAs on common permutation test problems: Flow Shop Scheduling, Linear Ordering, Quadratic Assignment, and Travelling Salesman Problems.

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# Hybrid Estimation of Distribution Algorithm for No-Wait Flow-Shop Scheduling Problem with Sequence-Dependent Setup Times and Release Dates

Zhang, Zi-Qi Qian, Bin Hu, Rong Zhang, Chang-Sheng Li, Zi-Hui

This paper proposes an innovative hybrid estimation of distribution algorithm (HEDA) for the no-wait flow-shop scheduling problem (NFSSP) with sequence dependent setup times (SDSTs) and release dates (RDs) to minimize the total completion time (TCT), which has been proved to be typically NP-hard combinatorial optimization problem with strong engineering background. Firstly, a speed-up evaluation method is developed according to the property of NFSSP with SDSTs and RDs. Secondly, the genetic information both order of jobs and the promising blocks of jobs are concerned to generate the guided probabilistic model. Thirdly, after the HEDA based global exploration, a problem dependent local search is developed to emphasize exploitation. Due to the reasonable balance between HEDA based global search and problem-dependent local search as well as the comprehensive utilization of the speed-up evaluation, TCT-NFSSP with SDSTs and RDs can be solved effectively and efficiently. Computational results and comparisons demonstrate the superiority of HEDA in terms of searching quality, robustness, and efficiency.

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# A Solution to Economic Dispatch Problem Using Heuristic based Optimisation Under Pool Market with Elastic Demand and Efficient Generation

Das, Debraj Mullick, Baishali Karthikeyan, S. Prabhakar

With the current level of pollution in atmosphere caused by fossil fuel emissions, coupled with the ominous fuel scarcity, efficient generation at the power stations is necessary. This paper proposes a multi-objective optimization model to maximize social welfare using the Bees Foraging Algorithm (BFA) and Estimation of Distribution Algorithm (EDA) highlighting the importance of treating generator efficiency parameters along with generation bid. This is because the generator bids alone are a poor representation of efficiency, being influenced by economic attitudes. Along with Economic Load Dispatch (ELD), the model reduces fossil fuel emissions and increases the efficiency of operating generators through curtailment to shift the operating point of generators to a more efficient region, while maintaining constraints of the system. The generation side curtailment is reflected on distribution side, where curtailment schemes based on the willingness to pay of the consumer and priority based incentive is used, thereby performing environmental dispatch. The improved efficiency reduces fuel consumption per MW thereby reducing fuel cost (Rs/h) and emission (ton/h), therefore maintaining generation efficiency with profit retention. The paper therefore establish that Independent System Operator (ISO), by real-time control of incentives and curtailment, encourage efficient consumption pattern among consumers and production among generating companies (GENCO). The results confirm that the proposed model benefits the society i.e. consumers, power producers and the environment.

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# Large-Scale Global Optimization Using a Binary Genetic Algorithm with EDA-Based Decomposition

Sopov, Evgenii

In recent years many real-world optimization problems have had to deal with growing dimensionality. Optimization problems with many hundreds or thousands of variables are called large-scale global optimization (LGSO) problems. The most advanced algorithms for LSGO are proposed for continuous problems and are based on cooperative coevolution schemes using the problem decomposition. In this paper a novel technique is proposed. A genetic algorithm is used as the core technique. The estimation of distribution algorithm is used for collecting statistical data based on the past search experience to provide the problem decomposition by fixing genes in chromosomes. Such an EDA-based decomposition technique has the benefits of the random grouping methods and the dynamic learning methods. The results of numerical experiments for benchmark problems from the CEC' 13 competition are presented. The experiments show that the approach demonstrates efficiency comparable to other advanced algorithms.

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# Fast Solutions Enhancing using a Copula-based EDA and SVM for many-objective problems

Cheriet, Abdelhakim Cherif, Foudil Taleb-Ahmed, Abdelmalik

In this paper we propose a new Copula-based Estimation of Distribution Algorithm, to solve Many-objective optimization problem and to get new optimal solutions in very court time. Our algorithm uses the proprieties of Copula and exploits their statistical properties to make new solutions using the founded optimal solutions through the estimation of their distribution. The first step of the proposed Copula-based Estimation of Distribution Algorithm (CEDA-SVM) is taking initial solutions offered by any MOEA (Multi Objective Evolutionary Algorithm), and then creates Copulas to estimate their distribution, and we use Support Vector Machine (SVM) to learn the Pareto solutions model; those Copulas will be used to generate new solutions and SVM to avoid the expensive function evaluations. The idea of using the estimated distribution of the optimal solutions helps CEDA-SVM to avoid running the optimizer (MOEA) every time we need new alternatives solutions when the founded ones are not satisfactory. We tested CEDA-SVM on a set of many-objective benchmark problems traditionally used by the community, namely DTLZ (1, 2, 3, and 4) with different dimensions (3, 5, 8, 10, and 15). We used CEDA along with MOEA/D-Schy and MOEA/D-BI as two examples of MOEA thus resulting in two variants CEDA-MOAE/D-Sey and CEDA-MOEA/D-BI and compare them with MOEA/D-Schy and MOEA/D-BI. The results of our experiments show that, with both variants of CEDA-SVM, new solutions can be obtained in a very small time compared to the other algorithms. (C) 2016, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.

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# EDAs cannot be Balanced and Stable

Friedrich, Tobias Koetzing, Timo Krejca, Martin S.

Estimation of Distribution Algorithms (EDAs) work by iteratively updating a distribution over the search space with the help of samples from each iteration. Up to now, theoretical analyses of EDAs are scarce and present run time results for specific EDAs. We propose a new framework for EDAs that captures the idea of several known optimizers, including PBIL, UMDA, A-MMASIB, cGA, and (1,lambda)-EA.

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# Finding Interactions or Relationships Between Customer Orders for Building Better Batches by Means of an Estimation of Distribution Algorithm-based approach for the Online Order Batching Problem

Perez-Rodriguez, Ricardo Hernandez-Aguirre, Arturo

Order-picking systems are very common in industry. In this warehouse environment an order batching consists of combining customer orders into picking orders. Order batching is a combinatorial issue because many customer orders arrive throughout the scheduling in real-world situations, therefore to find interactions or relationships between orders for building better batches is a difficult task. This paper introduces an estimation of distribution algorithm-based approach for the online order batching problem to guide the overall search process. The results show how the warehouse performance is improved by estimating relationships between orders. This approach is compared with others published in the literature.

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# Expanding from Discrete Cartesian to Permutation Gene-pool Optimal Mixing Evolutionary Algorithms

Bosman, Peter A. N. Ngoc Hoang Luong Thierens, Dirk

The recently introduced Gene-pool Optimal Mixing Evelutionary Algorithm (GOMEA) family, which includes the Linkage Tree Genetic Algorithm (LICA), has been shown to scale excellently on a variety of discrete, Cartesian-space, optimization problems. This paper shows that GOMEA can quite straightforwardly also be used to solve permutation optimization problems by employing the random keys encoding of permutations. As a test problem, we consider permutation flowshop scheduling, minimizing the total flow time an 120 different problem :instances (Taillard benchmark). The performance of GOMEA is compared with the recently published generalized Mallows estimation of distribution algorithm (GM-EDA). Statistical tests show that results of GOMEA variants are almost always significantly better than results of GM-EDA. Moreover, even without using local search, the new GOMEA variants obtained the best-known solution for 30 instances in every run and even new upper bounds for several instances. Finally, the time complexity per solution for building a dependency model to drive variation is an order of complexity less for GOMEA than for GM-FDA, al together suggesting that GOMEA also holds much promise for permutation optimization.

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# A Novel Multi-objective Optimization-based Image Registration Method

Shi, Meifeng He, Zhongshi Chen, Ziyu Zhang, Hang

The RANSAC is widely used in image registration algorithms. However, the RANSAC becomes computationally expensive when the number of feature points is large. And also, its high error matching ratio caused by the large number of iterations always raises the possibility of false registration. To deal with these drawbacks, a novel multi-objective optimization-based image registration method is proposed, named MO-IRM. In MO-IRM, a multi-objective estimation model is built to describe the feature matching pairs (data set), with no need for the pre-check process that is necessary in some improved RANSAC algorithms to eliminate the error-matching pairs. Moreover, a full variate Gaussian model-based RM-MEDA without clustering process (FRM-MEDA) is presented to solve the established multi-objective model. FRM-MEDA only requires a few iterations to find out a correct model. FRM-MEDA can not only greatly reduce the computational overhead but also effectively decrease the possibility of false registration. The proposed MO-IRM is compared with RM-MEDA, NSGA-square and the RANSAC based registration algorithm on the Dazu grottoes image database. The experiment results demonstrate that the proposed method achieves ideal registration performances on both two images and multiple images, and greatly outperforms the compared algorithms on the runtime.

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# Evolutionary Approaches to Optimization Problems in Chimera Topologies

Santana, Roberto Zhu, Zheng Katzgraber, Helmut

Chimera graphs define the topology of one of the first commercially available quantum computers. A variety of optimization problems have been mapped to this topology to evaluate the behavior of quantum enhanced optimization heuristics in relation to other optimizers, being able to efficiently solve problems classically to use them as benchmarks for quantum machines. In this paper we investigate for the first time the use of Evolutionary Algorithms (EAs) on Ising spin glass instances defined on the Chimera topology. Three genetic algorithms (GAs) and three estimation of distribution algorithms (EDAs) are evaluated over 1000 hard instances of the Ising spin glass constructed from Sidon sets. We focus on determining whether the information about the topology of the graph can be used to improve the results of EAs and on identifying the characteristics of the Ising instances that influence the success rate of GAs and EDAs.

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# HMOBEDA: Hybrid Multi-objective Bayesian Estimation of Distribution Algorithm

Martins, Marcella S. R. Delgado, Myriam R. B. S. Santana, Roberto Luders, Ricardo Goncalves, Richard Aderbal de Almeida, Carolina Paula

Probabilistic modeling of selected solutions and incorporation of local search methods are approaches that can notably improve the results of multi-objective evolutionary algorithms (MOEAs). In the past, these approaches have been jointly applied to multi-objective problems (MOPs) with excellent results. In this paper, we introduce for the first time a joint probabilistic modeling of (1) local search methods with (2) decision variables and (3) the objectives in a framework named HMOBEDA. The proposed approach is compared with six evolutionary methods (including a modified version of NSGA-III, adapted to solve combinatorial optimization) on instances of the multi-objective knapsack problem with 3, 4, and 5 objectives. Results show that HMOBEDA is a competitive approach. It outperforms the other methods according to the hypervolume indicator.

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# Benchmarking RM-MEDA on the Bi-objective BBOB-2016 Test Suite

Auger, Anne Brockhoff, Dimo Hansen, Nikolaus Tusar, Dejan Tusar, Tea Wagner, Tobias

In this paper, we benchmark the Regularity Model-Based Multiobjective Estimation of Distribution Algorithm (RM-MEDA) of Zhang et al. on the bi-objective bbob-biobj test suite of the Comparing Continuous Optimizers (COCO) platform. It turns out that, starting from about 200 times dimension many function evaluations, RM-MEDA shows a linear increase in the solved hypervolume-based target values with time until a stagnation of the performance occurs rather quickly on all problems. The final percentage of solved hyper-volume targets seems to decrease with the problem dimension.

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# Ant Colony Optimization Beats Resampling on Noisy Functions

Friedrich, Tobias Koetzing, Timo Quinzan, Francesco Sutton, Andrew M.

Despite the pervasiveness of noise in real-world optimization, there is little understanding of the interplay between the operators of randomized search heuristics and explicit noise handling techniques such as statistical resampling. Ant Colony Optimization (ACO) algorithms are claimed to be particularly well-suited to dynamic and noisy problems, even without explicit noise-handling techniques.

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# Minimizing makespan in a no-wait flowshop with two batch processing machines using estimation of distribution algorithm

Zhou, Shengchao Li, Xueping Chen, Huaping Guo, Cong

This paper studies the problem of minimising makespan in a no-wait flowshop with two batch processing machines (comprised of a parallel batch processing machine and a serial batch processing machine), non-identical job sizes and unequal ready times. We propose a population-based evolutionary method named estimation of distribution algorithm (EDA). Firstly, the individuals in the population are coded into job sequences. Then, a probabilistic model is built to generate new population and an incremental learning method is developed to update the probabilistic model. Thirdly, the best-fit heuristic is used to group jobs into batches and a least idle/waiting time approach is proposed to sequence the batches on batch processing machines. In addition, some problem-dependent local search heuristics are incorporated into the EDA to further improve the searching quality. Computational simulation and comparisons with some existing algorithms demonstrate the effectiveness and robustness of the proposed algorithm. Furthermore, the effectiveness of embedding the local search method in the EDA is also evaluated.

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# A Targeted Estimation of Distribution Algorithm Compared to Traditional Methods in Feature Selection

Neumann, Geoffrey Cairns, David

The Targeted Estimation of Distribution Algorithm (TEDA) introduces into an EDA/GA hybrid framework a 'Targeting' process, whereby the number of active genes, or 'control points', in a solution is driven in an optimal direction. For larger feature selection problems with over a thousand features, traditional methods such as forward and backward selection are inefficient. Traditional EAs may perform better but are slow to optimize if a problem is sufficiently noisy that most large solutions are equally ineffective and it is only when much smaller solutions are discovered that effective optimization may begin. By using targeting, TEDA is able to drive down the feature set size quickly and so speeds up this process. This approach was tested on feature selection problems with between 500 and 20,000 features using all of these approaches and it was confirmed that TEDA finds effective solutions significantly faster than the other approaches.

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# Probability model to Solve the School Bus Routing Problem with Stops Selection

Perez-Rodriguez, Ricardo Hernandez-Aguirre, Arturo

This paper describes the use of a new algorithm that solves the school bus routing problem with stops selection. The aim is to reduce the travel time of a set of buses that transport students to a school. The fundamental contribution of the authors is the use of a probability model to describe the feasible solution space distribution and thus to get the best solution. An estimation of distribution algorithm is used to address the combinatorial complexity of the problem statement. Different and better results are obtained with the proposed algorithm against a genetic algorithm. The contribution of this paper is to propose an alternative to solve permutation-based representation problems with logistics application.

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# A hybrid differential evolution and estimation of distribution algorithm based on neighbourhood search for job shop scheduling problems

Zhao, Fuqing Shao, Zhongshi Wang, Junbiao Zhang, Chuck

Job shop scheduling problem (JSSP) is a typical NP-hard problem. In order to improve the solving efficiency for JSSP, a hybrid differential evolution and estimation of distribution algorithm based on neighbourhood search is proposed in this paper, which combines the merits of Estimation of distribution algorithm and Differential evolution (DE). Meanwhile, to strengthen the searching ability of the proposed algorithm, a chaotic strategy is introduced to update the parameters of DE. Two mutation operators are adopted. A neighbourhood search (NS) algorithm based on blocks on critical path is used to further improve the solution quality. Finally, the parametric sensitivity of the proposed algorithm has been analysed based on the Taguchi method of design of experiment. The proposed algorithm was tested through a set of typical benchmark problems of JSSP. The results demonstrated the effectiveness of the proposed algorithm for solving JSSP.

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# An Integrated Method Based on PSO and EDA for the Max-Cut Problem

Lin, Geng Guan, Jian

The max-cut problem is NP-hard combinatorial optimization problem with many real world applications. In this paper, we propose an integrated method based on particle swarm optimization and estimation of distribution algorithm (PSO-EDA) for solving the max-cut problem. The integrated algorithm overcomes the shortcomings of particle swarm optimization and estimation of distribution algorithm. To enhance the performance of the PSO-EDA, a fast local search procedure is applied. In addition, a path relinking procedure is developed to intensify the search. To evaluate the performance of PSO-EDA, extensive experiments were carried out on two sets of benchmark instances with 800 to 20000 vertices from the literature. Computational results and comparisons show that PSO-EDA significantly outperforms the existing PSO-based and EDA-based algorithms for the max-cut problem. Compared with other best performing algorithms, PSO-EDA is able to find very competitive results in terms of solution quality.

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# Classifier Subset Selection for the Stacked Generalization Method Applied to Emotion Recognition in Speech

Alvarez, Aitor Sierra, Basilio Arruti, Andoni Lopez-Gil, Juan-Miguel Garay-Vitoria, Nestor

In this paper, a new supervised classification paradigm, called classifier subset selection for stacked generalization (CSS stacking), is presented to deal with speech emotion recognition. The new approach consists of an improvement of a bi-level multi-classifier system known as stacking generalization by means of an integration of an estimation of distribution algorithm (EDA) in the first layer to select the optimal subset from the standard base classifiers. The good performance of the proposed new paradigm was demonstrated over different configurations and datasets. First, several CSS stacking classifiers were constructed on the RekEmozio dataset, using some specific standard base classifiers and a total of 123 spectral, quality and prosodic features computed using in-house feature extraction algorithms. These initial CSS stacking classifiers were compared to other multi-classifier systems and the employed standard classifiers built on the same set of speech features. Then, new CSS stacking classifiers were built on RekEmozio using a different set of both acoustic parameters (extended version of the Geneva Minimalistic Acoustic Parameter Set (eGeMAPS)) and standard classifiers and employing the best meta-classifier of the initial experiments. The performance of these two CSS stacking classifiers was evaluated and compared. Finally, the new paradigm was tested on the well-known Berlin Emotional Speech database. We compared the performance of single, standard stacking and CSS stacking systems using the same parametrization of the second phase. All of the classifications were performed at the categorical level, including the six primary emotions plus the neutral one.

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# User Adapted Motor-Imaginary Brain-Computer Interface by means of EEG Channel Selection Based on Estimation of Distributed Algorithms

Astigarraga, Aitzol Arruti, Andoni Muguerza, Javier Santana, Roberto Martin, Jose I. Sierra, Basilio

Brain-Computer Interfaces (BCIs) have become a research field with interesting applications, and it can be inferred from published papers that different persons activate different parts of the brain to perform the same action. This paper presents a personalized interface design method, for electroencephalogram-(EEG-) based BCIs, based on channel selection. We describe a novel two-step method in which firstly a computationally inexpensive greedy algorithm finds an adequate search range; and, then, an Estimation of Distribution Algorithm(EDA) is applied in the reduced range to obtain the optimal channel subset. The use of the EDA allows us to select the most interacting channels subset, removing the irrelevant and noisy ones, thus selecting the most discriminative subset of channels for each user improving accuracy. The method is tested on the IIIa dataset from the BCI competition III. Experimental results show that the resulting channel subset is consistent with motor-imaginary-related neurophysiological principles and, on the other hand, optimizes performance reducing the number of channels.

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# Quantitative optimization of interoperability during feature-based data exchange

Zhang, D. J. He, F. Z. Han, S. H. Li, X. X.

Sharing feature-based computer-aided design (CAD) models is a challenging problem that is frequently encountered among heterogeneous CAD systems. In this work, a new asymmetric strategy is presented to enrich the theory of feature-based interoperability, particularly when addressing a singular feature or singular sketch. This paper analyzes the semantic asymmetry singular feature interoperability (SA-SFI) and parameter asymmetry singular sketch interoperability (PA-SSI) in detail. We pay special attention to the problem of PA-SSI, which is universally significant in collaborative product development (CPD). The objective of PA-SSI is to develop an optimized model to exchange a singular sketch (spline) to ensure that the exchanged model both maintains high geometric fidelity and can be effectively edited in the target CAD system. The proposed method applies the estimation of distribution algorithm (EDA) to automatically solve this problem, and a Gaussian mixture model (GMM) is built according to the promising solutions. Furthermore, Hausdorff distance is adopted to calculate the fitness, and a local optimization operator is designed to enhance the global search capability of the population. Experimental results demonstrate that the proposed approach can maintain a sufficiently high geometric fidelity, and ensure that the exchanged model of the target CAD system can be parametrically edited.

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# A hybrid heuristic for dominating tree problem

Chaurasia, Sachchida Nand Singh, Alok

Given an undirected, connected, edge-weighted graph, the dominating tree problem (DTP) seeks on this graph a tree of minimum weight such that each node of the graph either belongs to the tree or is adjacent to a node in the tree. This problem is -hard. In this paper, we present an evolutionary algorithm with guided mutation (EA/G) to solve the DTP. This problem has several practical applications in the field of wireless sensor networks. EA/G is a recently proposed evolutionary algorithm that tries to overcome the shortcomings of genetic algorithms (GAs) and estimation of distribution algorithms both, and has the characteristics of both. We have compared the performance of our proposed approach with the state-of-the-art approaches presented in the literature. Computational results show the superiority of our approach in terms of solution quality as well as execution time.

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# An Estimation of Distribution Algorithm-Based Memetic Algorithm for the Distributed Assembly Permutation Flow-Shop Scheduling Problem

Wang, Sheng-Yao Wang, Ling

In this paper, an estimation of distribution algorithm (EDA)-based memetic algorithm (MA) is proposed for solving the distributed assembly permutation flow-shop scheduling problem (DAPFSP) with the objective to minimize the maximum completion time. A novel bi-vector-based method is proposed to represent a solution for the DAPFSP. In the searching phase of the EDA-based MA (EDAMA), the EDA-based exploration and the local-search-based exploitation are incorporated within the MA framework. For the EDA-based exploration phase, a probability model is built to describe the probability distribution of superior solutions. Besides, a novel selective-enhancing sampling mechanism is proposed for generating new solutions by sampling the probability model. For the local-search-based exploitation phase, the critical path of the DAPFSP is analyzed to avoid invalid searching operators. Based on the analysis, a critical-path-based local search strategy is proposed to further improve the potential solutions obtained in the EDA-based searching phase. Moreover, the effect of parameter setting is investigated based on the Taguchi method of design-of-experiment. Suitable parameter values are suggested for instances with different scales. Finally, numerical simulations based on 1710 benchmark instances are carried out. The experimental results and comparisons with existing algorithms show the effectiveness of the EDAMA in solving the DAPFSP. In addition, the best-known solutions of 181 instances are updated by the EDAMA.

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# A fuzzy logic-based hybrid estimation of distribution algorithm for distributed permutation flowshop scheduling problems under machine breakdown

Wang, Kai Huang, Yun Qin, Hu

As the research interest in distributed scheduling is growing, distributed permutation flowshop scheduling problems (DPFSPs) have recently attracted an increasing attention. This paper presents a fuzzy logic-based hybrid estimation of distribution algorithm (FL-HEDA) to address DPFSPs under machine breakdown with makespan criterion. In order to explore more promising search space, FL-HEDA hybridises the probabilistic model of estimation of distribution algorithm with crossover and mutation operators of genetic algorithm to produce new offspring. In the FL-HEDA, a novel fuzzy logic-based adaptive evolution strategy (FL-AES) is adopted to preserve the population diversity by dynamically adjusting the ratio of offspring generated by the probabilistic model. Moreover, a discrete-event simulator that models the production process under machine breakdown is applied to evaluate expected makespan of offspring individuals. The simulation results show the effectiveness of FL-HEDA in solving DPFSPs under machine breakdown.

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