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Cellular Evolutionary Algorithms with Estimation of Distribution

Yoan Martínez-López[1], Julio Madera[1], Ansel Rodríguez[2]

[1] University of Camagüey, Cuba

[2] Centro de Investigación Científica y de Educación Superior de Ensenada, Unidad de Transferencia Tecnológica UT3, Mexico

{yoan.martinez, julio.madera}@reduc.edu.cu, ansel@cicese.mx

Abstract. In this research, a class of evolutionary algorithms (EA), called Cellular Estimation of Distribution Algorithms (CEDA) are proposed for discrete and continuous optimization problems. The main intention is to study the efficiency of EDA from two perspectives: to decrease the number of objective function evaluations (evaluative efficiency) and the execution time of the algorithm (time efficiency). First, a study is reported on the use of Bayesian models that use constraint-based independence detection for learning the structure of the probabilistic model. As a result, three algorithms are created: CEBA, CEGA and CUMDANCAUCHY, which were validated with different datasets.

Keywords: Cellular EDA, evolutionary algorithms, learning, probabilistic graphical models.

1 Introduction

Evolutionary Computation (EC) is one of the branches of Artificial Intelligence applied to solve combinatorial optimization problems, which is inspired by the mechanisms of biological evolution proposed by Darwin, Medel and Lamark where Darwin proposed the "Natural Selection of the Most Adapted", Medel proposed the "Corpuscular Theory of Inheritance" and Lamark proposed the "Inheritance of Acquired Characteristics" [1, 3]. EDAs (Estimation Distribution Algorithms) are a group of evolutionary algorithms that allow fitting the model to the structure of a given problem, made by an estimation of probability distributions from selected solutions. The model reflected by the bias is a probability distribution [2]. Cellular evolutionary algorithms belong to the class of evolutionary algorithms of discrete groups based on spatial structures, where each individual interacts with his or her adjacent neighbor. An overlapping neighborhood assists in the exploration of the search space, while exploitation takes place within a neighborhood by stochastic operators [2]. A cellular EDA is a collection of decentralized collaborative collections of EDAs, also called member algorithms, that develop overlapping populations, where the organization of cellular EDAs is based on the traditional 2D (two-grid) structure of overlapping neighbors, where one grid contains chains, and the other contains disjointed sets of chains (cells) [2].

2 Research Question

How to use structured populations in EDA to building efficient algorithms from the fitness function evaluation point of view?

3 General Objective

To develop EDA algorithms with evidence-based learning of independence and decentralized schemes to reduce the number of evaluations in solving discrete and continuous optimization problems.

4 Specific Objectives

To create decentralized (cellular) EDA models that are more efficient evaluative than the centralized one.

To create decentralized EDA algorithms that use independence tests in learning to reduce the number of evaluations of state-of-the-art algorithms that use metrics optimization.

5 Hypothesis

Developing decentralized EDA algorithms that use independence testing in learning increases assessment efficiency with respect to centralized EDA.

6 Proposed Learning Strategies

Three learning strategies are proposed in this research:

1) Learning the structure and parameters from local populations.
2) Learning structure from the global population and parameters from local populations.
3) Learning structure from the global population, but calculating the necessary statistics locally and then integrating the results with an appropriate statistical method.

7 Contributions

Our contribution was the development of three algorithms: CEBA (Cellular Estimation Bayesian Algorithm), CEGA (Cellular Estimation Gaussian Algorithm), and

Table 1. Result of the first five places of GECCO/WCCI 2020[1].

Algorithm	Ranking Index
CUMDANCauchy++	5.48
DEEDA	5.41
CBBO, Cauchy and DEEPSO	5.34
HFEABC	5.00
DE-TLBO	4.54

CUMDANCAUCHY (Cellular Univariate Marginal Distribution Algorithm with Normal-Cauchy distribution), which were evaluated with different datasets of discrete and continuous domain. Moreover, CUMDANCAUCHY was applied in some real-world problems, such as: energy resource management in smart grid and CVRP (Capacited Vehicle Routing Problem) problem applied health resources.

8 Experiments and Results

We used three domains for performing experiments: benchmarks discrete function, continuous function, and real-world problem.

Discrete functions benchmark. The preliminary experiments on discrete functions verify the effectiveness of the CEBA. The aim of these benchmark functions is to test the performance of the discrete optimization algorithms. The IsoPeak, FirstPolytree3, OneMax, Deceptive3 and Plateu functions were used. All results are shown in [9].

Continuous functions benchmark. The behavior of the proposed algorithm CEGA is evaluated using a comparison in terms of the approximation to the optimum and the numbers of iterations and evaluations needed for different neighborhoods are presented over the continuous functions: Griewangk, Rastrigin's, Rosenbrock's, Sphere and Ackley's. CEGA is compared with the other continuous EDAs reported in the literature for the same continuous functions. All results are shown in [7].

Real-world problem. To test the proposed algorithm, the framework developed for the competition: "Evolutionary Computation in Uncertain Environments: A Smart Grid Application" was used [4, 5]. CUMDANCauchy outperforms the winner's algorithms of the 2018 edition, emerging as a good tool to solve the ERM problem under uncertainty. Moreover, EDAs and hybrid EDAs methodologies achieved good results compared with the baseline algorithm (DE). In general, the experimental results showed that EDAs and hybrid EDAs methodologies are good tools to solve the ERM problem under uncertainty. Next, experimentation with 15 models to study the behavior of the algorithms applied to the problem, using the CVRP library, implemented in MATLAB was done. Three metaheuristics models were implemented: Estimation of Distributions Algorithms, Simulated Annealing and Variable Neighborhood Search. From the modelled problem, it was proceeded to solve the FSMVRPTW problem using EDA, SA and VNS algorithms [3]. The studies about the CVRP have demonstrated its usefulness in different complex situations as pandemic, to optimize the distribution of

[1] http://www.gecad.isep.ipp.pt/ERM-competitions/2020-2/

resources. Table 1 shows the result of the GECCO/WCCI 2020 competition, taking into account the Ranking Index, where CUMDANCauchy++ and DEEDA were the best algorithms [4, 5].

9 Conclusions

Cellular EDAs with evidence-based learning of independence may increase the evaluative efficiency of the EDA by the way the population is structured and the interaction between the different algorithms. As future work, adapting cEDA for practical problems where there are dependencies amongst the variables and the number of evaluations of the fitness functions is restricted will be an interesting research direction. Another interesting work will be comparing cEDA with other algorithms like Differential Evolution Algorithm, Particle Swarm Optimization and Firefly Algorithm in this kind of problems.

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