CUMDANCauchy-C1: a Cellular EDA Designed to Solve the Energy Resource Management Problem Under Uncertainty

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ABSTRACT

One step in the way to sustainable cities and society is the massive growth of electric vehicles and producers of renewable energy (RE) like sun and wind. But these advances are a challenge in the more efficient management of energy due to the uncertainty that they incorporate into the problem. In this paper, a Cellular Estimation Distribution algorithm (CUMDANCauchy-C1) is designed to Solve the Energy Resource Management Problem Under Uncertainty. CUMDANCauchy-C1 is a cellular evolutionary algorithm with univariate estimation and neighborhood One, which learn a combination of Normal and Cauchy distributions from the global population to generate the new individuals.

The framework developed for the "2019 Evolutionary Computation in Uncertain Environments: A Smart Grid Application" was used to test the proposed algorithm. Also a comparison, in the current competition framework, with the winners algorithms of the 2018 edition was done . The experimental results showed that CUMDANCauchy-C1 outperforms the winners algorithms of the 2018 edition.

CCS CONCEPTS

• **Computing methodologies → Planning under uncertainty**.

KEYWORDS

smart grids, evolutionary computation, uncertain environments, cellular estimation distribution algorithms

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1 INTRODUCTION

One step in the way to sustainable cities and society is the massive growth of electric vehicles and producers of renewable energy like sun and wind. But these advances are a challenge in the more efficient management of energy due to the uncertainty that they incorporate into the problem. Current smart grids include electric vehicles, energy storage systems, different types of distribute generation, demand response programs, vehicle-to-grid functionalities, market bids, external suppliers participation and AC network power balance constraints [6, 9, 10]. In this context, the Energy Resource Management (ERM) [5, 8] is a highly complex problem (a Mixed Integer Non-Linear Problem) with the objective of maximizing profits by reducing the need to buy energy from the day-ahead market or external suppliers at high prices.

For this problem, a framework of the energy resource management problem, was recently developed. Also, the competition: Evolutionary Computation in Uncertain Environments: A Smart Grid Application was launched in 2018 [2]. A new a framework and a new edition of the competition was launched in 2019 [3]. The 2019 framework introduce uncertainty regarding renewable generation, load forecast, electric vehicles scheduling and market prices.

Evolutionary Algorithms in particular Particle Swarm Optimization showed that can achieved near-optimal solutions in 2018 competition[1].

In this paper, a Cellular Estimation Distribution algorithm (CUMDANCauchy -C1) is designed to solve the ERM Problem Under Uncertainty. Also a comparison, in the current competition framework, with the winners algorithms of the 2018 edition was done.

2 CUMDANCAUCHY-C1

Estimation distribution algorithms (*EDAs*) is a kind of optimization algorithms based on substituting the crossover and mutation operators of the Genetic Algorithms by the estimation and later sampling the probability distribution learned from the selected individuals [4]. A particular kind of *EDAs* are Cellular *EDAs* which are a collection

[1] http://www.gecad.isep.ipp.pt/WCCI2018-SG-COMPETITION/

Algorithm 1 Cellular Univariate Marginal Distribution Algorithm with Normal-Cauchy distribution and neighborhood One (CUMDANCauchy-C1)

$t \leftarrow 1$
Generate N individuals randomly
while *not terminationCriteria* **do**
  Select globally $M \leq SizeOf(Neighborhood) \times SizeOf(cell)$ individuals of the neighborhood
  Estimate the combination of Normal and Cauchy distributions $N(\mu, \sigma) \times Cauchy(\mu, \sigma)$ of the M selected individuals
  for all cell **do**
    Generate $SizeOf(cell)$ new individuals according to the estimated distribution $N(\mu, \sigma) \times Cauchy(\mu, \sigma)$
    Insert the generated individuals in the same cell of an auxiliary population
  end for
  Replace the current population with the auxiliary one
  Compute and update the statistics
  $t \leftarrow t + 1$
end while

Table 1: Results of CUMDANCauchy-C1 and the best 2018 algorithms in the 2019 competition Evolutionary Computation in Uncertain Environments - A Smart Grid Application

Algorithms	RankingIndex	PAvgFit	PstdFit	PminFit	PmaxFit	PvarFit
CUMDANCauchy-C1	**123.93**	**61.32**	**62.61**	**8.64**	**363.44**	**3992.08**
Combination of VNS and Differential Evolutionary PSO	131.21	64.42	66.79	7.02	417.81	4542.71
Enhanced Velocity Differential Evolutionary PSO	150.37	73.47	76.88	-6.22	536.60	5916.90
Chaotic Evolutionary PSO	147.54	78.93	68.60	12.42	394.19	4770.90
PSO with Global Best Perturbation	161.60	81.32	80.27	-4.78	541.20	6443.60

of collaborative and decentralized *EDAs*, also called member algorithms that develop overlapping populations [1]. The organization of the cellular *EDAs* is based on the traditional structure of grids, where each grid contains a set of neighboring individuals, which form a cell. An interesting feature of these algorithms is they can reduces the number of evaluations of the fitness function in the search for optimums, maintaining its effectiveness in comparison to other *EDAs* [7].

The 2019 framework restricts the number of evaluations of the objective function to a maximum of 5000. Due it, we decided to design a Cellular *EDA* that can works with a small population (N = 10) to increase the number of possible iterations (500).

CUMDANCauchy-C1 is a cellular evolutionary algorithm with univariate estimation and neighborhood One (although other neighborhoods can be used), which learn a combination of Normal and Cauchy distributions from the global population to generate the new individuals (Algorithm1)

3 RESULTS AND CONCLUSIONS

To test the proposed algorithm, the framework developed for the competition:"2019 Evolutionary Computation in Uncertain Environments: A Smart Grid Application" was used. Also, a comparison, in the current competition framework, with the winners algorithms of the 2018 edition was done. Table 1 show the results over 20 repetitions of each algorithm.

CUMDANCauchy-C1 outperforms the winners algorithms of the 2018 edition, emerging as a good tool to solve the ERM problem under uncertainty.

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