Ring Cellular Encode-Decode UMDA: Simple is effective

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ABSTRACT

The management of today's smart grids is a challenge due to the stochastic nature of renewable energies, the vehicle-to-grid functionalities, the participation of external providers and the bidding in local and external markets. For this reason, the "Competition on Evolutionary Computation in the Energy Domain: Smart Grid Applications" with a framework to test algorithms for these problems is launched each year since 2017. In this paper, a novel algorithm named Ring Cellular Encode-Decode UMDA (RCED-UMDA) is introduced. The experimental results showed that RCED-UMDA achieves better average fitness for both tracks of the 2021 edition of this competition than the previous competition's algorithms.

CCS CONCEPTS

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

KEYWORDS

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

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1 INTRODUCTION

Smart grids coordinate generators, consumers, and prosumers to efficiently deliver sustainable, economical and secure electricity supplies [3]. Managing current smart grids is a challenge due to the stochastic nature of renewable energies, the vehicle-to-grid functionalities, the external suppliers participation, and bidding in local and external markets [8].

In this context, the research community has studied several smart grids management-related problems and provided a framework to test algorithms for these problems [4]. Also, the "Competition on Evolutionary Computation in the Energy Domain: Smart Grid Applications" with an updated framework has been launched each year since 2017. The 2021 edition of this competition [2] proposes two problems (tracks):

- Track 1. The optimization problem is a day-ahead local energy market bidding optimization problem, complex bi-level problem in which competitive agents in the upper-level try to maximize their profits, modifying and depending on the price determined in the lower-level problem (i.e., the clearing price in the local market), thus resulting in a strong interdependence of their decisions. This track is an update of the testbed 2 of the 2020 competition [1]. However, this time the maximum number of function evaluations is 10000.
- Track 2. The optimization problem is the flexibility management of home appliances to support distribution system operator requests. The problem considers an aggregator which is in control of the management of devices with demand response capabilities. The users register voluntarily for participation in flexibility provision receiving monetary compensation if their baseline profile is modified. The maximum number of function evaluations is 100000.

In this paper, a novel algorithm named *Ring Cellular Encode-Decode UMDA* (*RCED-UMDA*) is introduced. Also, preliminary results, and comparison, for the two tracks of the 2021 competition, with state-of-the-art algorithms, are presented.

2 RING CELLULAR ENCODE-DECODE UMDA

Ring Cellular Encode-Decode UMDA (*RCED-UMDA*) is Cellular Estimation of Distribution Algorithm (cEDA) distinguished by the following three aspects (algorithm 1). First, inspired on *CUMDANCauchy* [7], *RCED-UMDA* uses a cellular ring structure for partitioning the population into many small sub-populations or cells. Each cell, its l left cells, and its l right cells defines a neighborhood of individuals. Second, *RCED-UMDA* unlike others cDEAs for continuous domains [5, 6], reduces the search space converting the continuous variables into categorical variables in the reproductive cycle using an encoding method and later reconverting the categorical variables into continuous variables using a decoding method.

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Given the domain $[minB, maxB]$ of a continuous variable, a number of codes k, and a value $v \in [minB, maxB]$. The encoding method divides the domain into k uniform intervals and returns the index of the interval as the encode value ev. From ev, the decoding method returns $minB$ for the minimum ev, $maxB$ for the maximun ev, and for the others cases, the medium value of the interval with index ev for the others cases. Third, *RCED-UMDA* estimates the univariate marginal distribution $p(x) = \prod_{i=1}^{l} p(x_i)$ from the best individuals (encoded individuals) of the neighborhoods, scales each $p(x_i)$, and generates new individuals (encoded individuals) according to this distribution by probability sampling. Scaling method consists on increment the occurrences of all x_i in α value. As result none $p(x_i)$ is 0.

Algorithm 1: *Ring Cellular Encode-Decode UMDA*

Input: c - number of cells, m - size of the cells, $maxIt$ - maximum iteration, l - number of elitist individuals, s - number of selected individuals, r - neighborhood ratio, α - additional occurrence, k - number of codes, $minB$ - vector of min bounds, $maxB$ - vector of max bounds
Output: $bestSolution$ - best solution

```
t ← 1
Pop ← Create Ring cellular structure of c cells of size m
foreach cell do
    Pop(cell) ← m individuals generated randomly in [minB, maxB]
while t ≤ maxIt do
    Select globally l elitist individuals
    foreach cell do
        M ← the m best individuals in neighborhood(cell, r)
        eM ← encode(M, k, minB, maxB)
        Estimate the distribution p(x) = ∏_{i=1}^{l} p(x_i) from eM
        p(x) ← scale(p(x), α)
        eC ← c new individuals generating according to p(x)
        C ← decode(eC, k, minB, maxB)
        Insert C in the same cell of an auxiliary population auxPop
    Replace the Pop with auxPop
    Include the elitist individuals, replacing the individuals in their positions
    t ← t + 1
bestSolution ← the best individual in Pop
```

The parameters used in Algorithm 1 for track 1 are $c = 9$, $m = 10$, $maxIt = 111$, $l = 3$, $s = 30$, $r = 3$, $k = 7$ and $\alpha = 0.009$. For track 2 the parameters used are $c = 40$, $m = 15$, $maxIt = 166$, $l = 5$, $s = 90$, $r = 7$, $k = 31$ and $\alpha = 0.009$. The vector of minimum bounds $minB$ and the vector of maximum bounds $maxB$ are provided by the simulation framework.

3 RESULTS AND CONCLUSIONS

Table 1 shows the results over 20 independent runs of each algorithm (our proposed algorithm *RCED-UMDA*, the 2021 framework baseline algorithm *HyDE*, and algorithms of the previous competition [1]). For algorithm *HyDE* we use the parameters provided by the 2021 framework for each track. For the other algorithms we use for the track 1 the parameters provided by the authors for the same problem of the previous competition, but only fixing the number of iteration to satisfy the corresponding maximum number of function evaluations. For the track 2, we use the same parameters of the track 1, again only fixing the number of iteration as the maximal value that satisfy the corresponding maximum number of function evaluations.

[1]The results of some algorithms are shown as ∗ because their genuine implementations do not run for the corresponding track in the 2021 framework.

Table 1: Average Fitness of the algorithms for Track 1 and 2 using the "2021 Evolutionary Computation in Uncertain Environments: A Smart Grid Application" competition framework

Algorithms	Avg Fit. T1	Rank T1	Avg Fit. T2	Rank T2
RCED-UMDA	1.566	1	4.828	1
HyDE	1.947	5	7.706	2
RDG3+DEEPSO	1.910	4	*	*
CE-CMAES	2.154	6	14.702	5
HFEABC	3.094	11	24.718	9
DE-TLBO	2.389	8	14.731	6
PSO GBP	32.633	13	26.533	10
GASAPSO	1.653	3	8.184	3
AJSO	1.625	2	9.459	4
CUMDANCauchy++	2.935	9	24.539	8
EHL-PS-VNSO	4.773	12	*	*
E-CBBO-Cauchy-DEEPSO	2.218	7	*	*
VNS-DEEPSO	*	*	*	*
DEEDA	3.045	10	17.016	7

The proposed algorithm *RCED-UMDA* achieved the best Average Fitness for both tracks. For Track 1 *RCED-UMDA* was followed by *AJSO*, *GASAPSO* and *RDG3+DEEPSO*. For Track 2 *RCED-UMDA* was followed by *HyDE*, and again by *GASAPSO* and *AJSO*.

As future work, we visualize to explore the impact of performing a local search over the best solution found by *RCED-UMDA*. Another interesting address is to develop a strategy to dynamically decide the number of uniform intervals for each variable during its evolutionary process.

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