A Modified BBO for Design and Optimization of Electromagnetic Systems

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Abstract—**Several improvements of the Biogeography Based Optimization (BBO), have been recently introduced, in order to increase the optimization performances of the standard BBO algorithm, namely M_mC_nBBO. In this paper we compare the different proposed variations and apply them to benchmark functions and standard electromagnetic problems.**

***Index Terms*—global optimization, Biogeography Based Optimization, Band-pass filter**

I. INTRODUCTION

Evolutionary global optimization is nowadays largely applied to different types of engineering problems [1]. Some of these approaches, *i.e.* Genetic Algorithm (GA) [2], Particle Swarm Optimization (PSO) [3] and their hybrids [4], are well-assessed but they require high computational time to optimize complex problems, as those involving electromagnetic aspects, thus the scientific community is still developing new techniques.

In the last recent years, among the newly introduced optimization algorithms, there is the Biogeography Based Optimization [5], based on the science of Biogeography, *i.e.* the study of the geographical distribution of biological organisms. BBO shows very good features when applied to benchmark functions, but it is less performing when used in some real-world problems (see e.g. [6]). For this reason several improved versions of the original algorithm has been recently proposed [7]-[10].

In particular, the authors have recently implemented a different migration model and the concept of cataclysms [11,12], with the aim of avoiding the algorithm stagnation. If the possibility of using different migration model has already been explored in [10], even if here they are used in a different way, the idea of cataclysm has been more recently introduced [11,12]. The here-presented results of the application of the proposed methods, named in the following M_mC_n-BBO, to several benchmark functions and real-world electromagnetic problems show their effectiveness.

II. BIOGEOGRAPHY BASED OPTIMIZATION

As mentioned, BBO is based on the study of the geographical distribution of biological organisms. Even if BBO shares some features with other evolutionary optimization methods, it has also some unique characteristics. In fact, in BBO the problem possible solutions are identified as islands or habitats, and its operators are based on the concept of migration, to share information between the problem solutions. In particular, the BBO algorithm introduces four new parameters: *suitability index variable* (SIV) represents a variable that characterize habitability in an island, i.e. in a solution; *habitat suitability index* (HSI), represents the goodness of the solution, similarly to the fitness score concept in GA; *immigration rate* (λ) indicates how likely a solution is to accept features from other solutions; *emigration rate* (μ) indicates how likely a solution is to share its features with other solutions.

A low performing habitat has a low emigration rate and high immigration rate (in fact, the maximum possible immigration rate occurs when there are zero species in the habitat), while a high performing solution has a high emigration rate and low immigration rate, in fact, when HSI increases, the number of species grows, the habitat becomes more crowded, and more species are able to leave the island to explore other possible habitats, thus increasing the emigration rate.

A. Modified Migration Model

Different modification regarding the migration model were proposed in [10], affecting the way λ and μ are updated during iterations. In particular, while in the standard BBO the migration model is linear:

$$\lambda = 1 - f(y)$$

$$\mu = f(y)$$

in order to improve the share of information between high performing solution, similarly to [10] two other model are here introduced, a quadratic one:

$$\lambda = \big(1 - f(y)\big)^2$$

$$\mu = f^2(y)$$

and a cosine migration:

$$\lambda = \frac{1}{2}(\cos(f(y)\cdot\pi) + 1)$$

$$\mu = \frac{1}{2}(-\cos(f(y)\cdot\pi) + 1)$$

B. Cataclysm

In order to avoid premature stagnation, a novel implicit restart procedure, named "cataclysm" was introduced in [11]: when the best HSI among all habitats did not improve in the last C_n iterations, all the habitats are destroyed (cataclysm) and new ones are randomly generated. In order to preserve the best habitat elitism applies and no cataclysm occurs again before at least *5n* generations have passed.

Therefore, by changing the migration model and n it is possible to obtain an (infinite) set of schemes, that are identified by a corresponding name; the first part of the algorithm name codified the type of migration model used: "M_L", "M_Q" and "M_C" indicates a scheme in which the migration model is respectively the linear, the quadratic or the cosine one, while n directly appears as the subscript of "C".

III. Preliminary Analysis

The recently proposed M_mC_n-BBO was tested against the standard BBO in order to to assess the best configuration, *i.e.* to define which is the best migration model and the proper separation between two following cataclysms, considering different values of n.

The standard BBO together with different variations of the M_mC_n-BBO have been applied first to several benchmark functions. Table I (from [12]) reports the final mean (μ) and standard deviation (σ) values for the optimization of the *step* and Griewank function (see eg. [5]). These data have been obtained as the average over 50 independent trials, and using a population of 20 individuals for 200 iterations; the first row of the table corresponds to the standard BBO (M_L, C_0). By analyzing these preliminary results the authors found that:

- the different migration models seem to have a small influence on the performances of the optimizer, even if the quadratic scheme seems to work almost always slightly better;
- the presence of the cataclysm plays a very important role in increasing the performances of the BBO, in conjunction with any of the migration models;
- it is more effective when the value of n is small, i.e. when cataclysms are quite frequent.

IV. Numerical Results

In view of these promising results, the proposed modified version of BBO has been checked against common electromagnetic problems, namely: the optimization of a microstrip filter (as shown in [12]) and the design of a planar array. In particular, an array of 9×9 elements is considered, with the element excitation (amplitude and phase) and position as free parameters. Here only the results relative to the optimization of a planar array are shown, but others will be presented at the conference.

The curves of convergence obtained as the average value over 10 independent trials with the standard BBO, the M_Q-BBO, the M_C-BBO and the M_QC_{10}-BBO are reported in Table II and plotted in Fig. 1. In this case the M_QC_{50}-BBO outperforms the other schemes, even if also other M_Q schemes gives good results.

Additional results, relative to other electromagnetic optimization problems, will be presented at the conference, showing that usually the best convergences are obtained with n equal to 5 or 10, generally in conjunction with the quadratic or linear migration scheme.

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The here considered standard BBO algorithm was taken from [13].

TABLE I. Final values of benchmark functions optimization, with different parameters (average over 50 trials)

Migration model: M_m	**Cataclysm: C_n**	**Step Function**		**Griewank function**	
		μ	σ	μ	σ
L	0	94.3	37.32	1.84	0.3
Q	0	59.4	21.48	1.42	0.19
C	0	75.9	36.44	1.77	0.4
L	5	0	0	0.024	0.014
Q	5	0	0	0.021	0.008
C	5	0	0	0.02	0.007
L	10	0.3	0.8	0.23	0.53
Q	10	0.98	6.36	0.135	0.32
C	10	1.36	9.33	0.26	0.63
L	20	65.66	63.5	1.51	0.88
Q	20	25.3	31.8	1.035	0.65
C	20	40.68	39.55	1.06	0.8

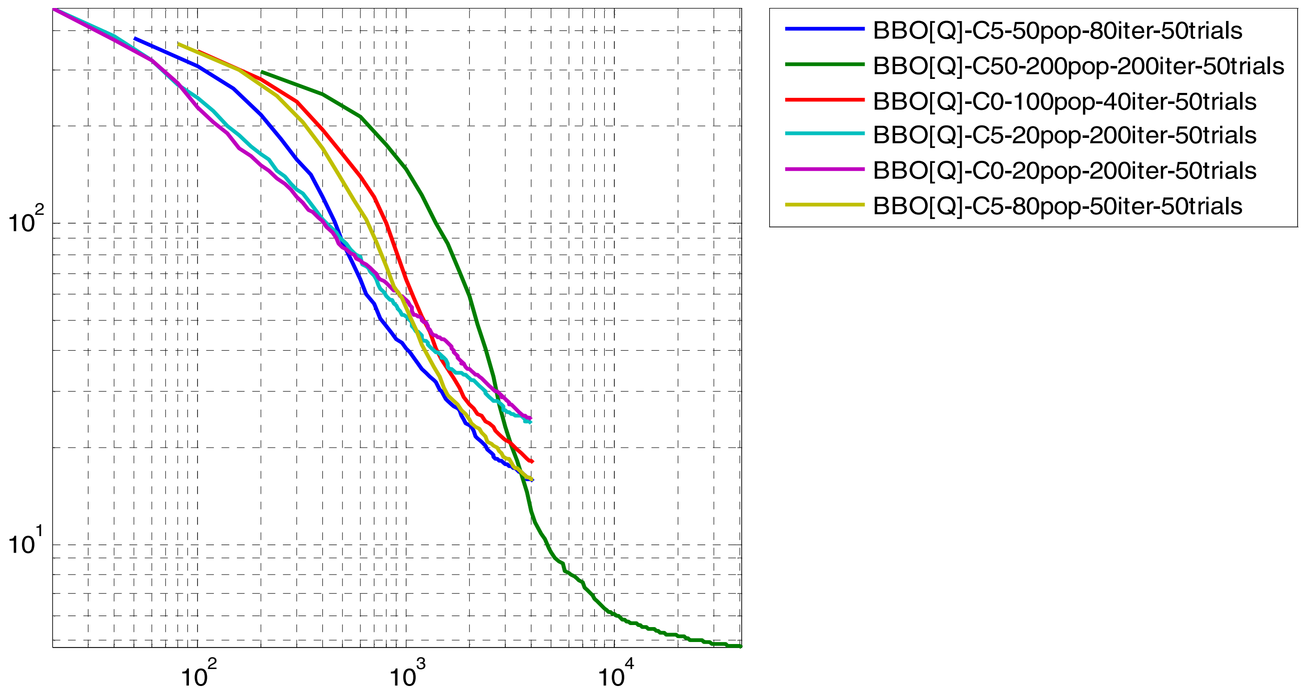

Figure 1. Convergences curves of the different considered schemes applied to the optimization of a planar array.

TABLE II. COMPARISON OF $M_M C_N$BBO FOR PLANAR ARRAY OPTIMIZATION

Migration model	Cataclysm *n*	Population	Iteration	Final value	Std. dev.
Q	50	200	200	4,7904	5,9645
Q	0	200	200	8,1484	7,7736
Q	0	200	20	14,6529	9,5654
Q	5	200	20	15,3996	11,4604
Q	5	100	40	15,4252	12,5037
Q	5	50	80	15,7631	13,6975
Q	5	80	50	15,9084	11,5191
Q	0	100	40	17,9288	12,8635
Q	5	20	200	19,3865	16,5959
Q	0	20	200	24,5947	19,8467
Q	50	20	200	25,144	18,2325
C	5	20	200	25,75	21,8699
L	5	20	200	26,4743	17,7922

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