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\textsubscript{m}C\textsubscript{n}-BBO. 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\textsubscript{m}C\textsubscript{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 ($\lambda$) indicates how likely a solution is to accept features from other solutions; emigration rate ($\mu$) 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 $\lambda$ and $\mu$ 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:

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

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 5\(n\) 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: 
\(“M_l“, “M_0“, “M_C“\) 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 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 (\(\mu\)) and 
standard deviation (\(\sigma\)) 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\times9 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 \(M_0\)- 
BBO, the \(M_C\)-BBO and the \(M_0C_{10}\)-BBO are reported in Table 
II and plotted in Fig. 1. In this case the \(M_0C_{50}\)-BBO 
outperforms the other schemes, even if also other \(M_0\) 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.

ACKNOWLEDGEMENT

This work is part of the ASPRI educational program of 
Politecnico di Milano; the students involved in this project are: 
Baldassarre Luca, Bargiacchi Edoardo, Bosetti Luca, Ceci 
Alessandro, Cioppa Gregorio, Cucci Edoardo, Gastaldello 
Niccolò, Massarweh Lotfi, Mulassano Loris, Nicolai 
Alessandro, Papetti Viola, Passoni Davide, Pelamatti Julien, 
Purpura Giovanni, Rossi Giorgio, Rossi Pietro, Rozza 
Eleonora, Sacramone Simone, Saetta Alessandro, Secondi 
Alessandro, Spinelli Marco.

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

<table>
<thead>
<tr>
<th>Migration model: (M_m)</th>
<th>Cataclysm: (C_n)</th>
<th>Step Function</th>
<th>Griewank function</th>
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<tr>
<td></td>
<td>(\mu)</td>
<td>(\sigma)</td>
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Figure 1. Convergences curves of the different considered schemes applied to the optimization of a planar array.

TABLE II. COMPARISON OF MMCNBBO FOR PLANAR ARRAY OPTIMIZATION

<table>
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<tr>
<th>Migration model</th>
<th>Cataclysm n</th>
<th>Population</th>
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REFERENCES


