Multiobjective Biogeography-Based Optimization Based on Predator-Prey Approach for the Brushless DC Wheel Motor Problem

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Abstract — Biogeography is the science that studies the geographical distribution and the migration of species in an ecosystem. In this paper, a multiobjective biogeography-based optimization (BBO) combined with a predator-prey (PPBBO) approach is proposed and validated in the constrained design of a brushless DC (Direct Current) wheel motor. Results demonstrated that the proposed PPBBO approach converged to promising solutions in terms of quality and dominance when compared with the classical BBO in a multiobjective version.

I. INTRODUCTION

Evolutionary algorithms have demonstrated over the past years good performance when solving optimization problems. Further, when the problem has discontinuities and many constraints, they are very suitable for finding a good solution in a very short time, while classical methods based on gradient information are not able or cannot be applied.

In this work, we will evaluate the performance of a recent optimization technique based on biogeography [1], which studies the geographical distribution and the migration of species in an ecosystem. The solutions are treated as habitats and the concepts and models of biogeography are applied in order to find a solution with good aspects.

The concept of predator-prey is also included in the biogeography algorithm in order to improve its capability of find a good solution [2]. Predators are included in the population of solutions for hunt the worst individuals and make the others solutions run away from that ones to avoid the predator [3].

These approaches are used to optimize the construction parameters of a brushless DC (Direct Current) wheel motor [4]. It is a multiobjective constrained problem with two objective functions: the efficiency and the mass of the motor.

The remainder of this paper is organized as follows: section II shows the basic concepts of the biogeography-based approaches, in section III is presented the formulation of the problem and the sections IV and V show the results and conclusion, respectively.

II. BIOGEOGRAPHY-BASED OPTIMIZATION

The Biogeography-based optimization (BBO) algorithm, [1], uses the concepts and models of biogeography. These models describe the migration of species from a habitat to another one and how species arise or become extinct. Each solution used in the algorithm is considered as a habitat. For habitat comparison is used a habitat suitability index (HSI) that measures the habitat goodness, which is related to several aspects as, for example, rainfall, flora and fauna diversities, topography, and environment temperature. All these aspects are called suitability index variables (SIV).

A good habitat has a high HSI, while a poor habitat has a low HSI. This means that good habitats have better aspects than the poor ones. Habitats with high HSI have a high immigration rate due to their good aspects, whereas poor habitats have a low immigration rate but a high emigration rate unlike good ones. The migration rates are direct related to the number of species in a habitat. So, a habitat with many species has a high emigration rate, because it is almost saturated, while habitats with few species have high immigration rate because do not have good conditions to live in. This migration process increases the diversity of the habitat and contributes for species information sharing and the mutation probability.

Fig. 1 shows the emigration and the immigration as a function of the number of species, where *I* and *E* represent the maximum rates of immigration and emigration, respectively, and *S* denotes the number of species.

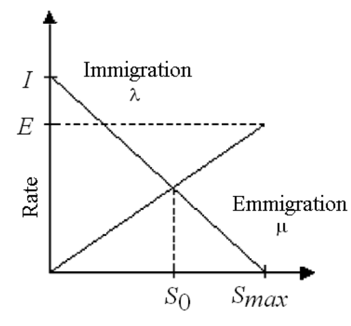

Fig. 1. Migration model.

These concepts are used in the BBO algorithm to find a good solution for a given problem, or a set of solutions in the case of multiobjective optimization problems.

A. *The Concept of Predator-Prey and the Biogeography-based Optimization*

In this paper, the concept of predator-prey is also used for increasing the diversity of the population and overcome local optimum traps. Two predators are included in the population, and then they will hunt the worst individuals of the population, i.e. the individuals with the worst values of the objective functions at the current iteration. Meanwhile the others individuals will run away from those ones to avoid the predators. This straightforward mechanism does not let the population to converge to a point in the search space improving the capability of exploration, and also forces the solutions to run onto the Pareto front. Also, this approach is called Predator-Prey Biogeography-based optimization (PPBBO).

III. PROBLEM FORMULATION

The problem approached in this work is the optimization of a brushless DC wheel motor for a race solar car [4]. This problem contains 10 optimization variables and 6 constraints. Figure 2 shows the geometry of the motor.

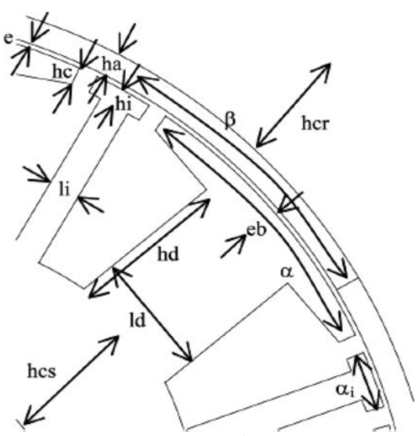

Fig. 2. Geometry of the motor.

Also, it is a multiobjective problem, where the objective functions are the maximization of the efficiency in percentage (f_1) and the minimization of the mass in kg (f_2).

The optimization variables are in Table I with their upper and lower boundaries. The only fixed variable is the number of pole-pairs, which is constant and equal to 6.

TABLE I
OPTIMIZATION VARIABLES

Variable (unit)	Description	Upper bound	Lower bound
D_s(mm)	Stator diameter	150	300
B_d(T)	Mean magnetic induction in the teeth	0.9	1.8
δ(A/mm^2)	Density current on the windings	2	5
B_e(T)	Induction in the air gap	0.5	0.76
B_{cs}(T)	Mean magnetic induction in the stator back iron	0.6	1.6
L_m(mm)	Magnetic length of the motor	30	90
r_{rs}	Ratio of the length rotor-stator	0.8	1.2
E	Air gap	0.3	2
B_{cr}(T)	Mean magnetic induction in the rotor back iron	0.6	1.6
U_{dc}(V)	DC bus voltage	50	200
P	Number of pole-pairs	6	6

IV. RESULTS

Tests were carried out in Matlab® (Mathworks). In order to avoid issues caused by randomness, 30 runs using different initial trial populations were made. The parameters were adjusted to: population size $P = 100$, number of generations $N = 100$, mutation probability $m = 0.5$ and, for the PPBBO approach is adopted hunting rate $\rho = 0.04$.

In Table II are presented the best results found over 30 runs. Figure 3 shows a comparison between the best fronts of the BBO and PPBBO. In terms of the minimum mass and maximum efficiency, BBO presents the best values. Nevertheless, when the diversity of the Pareto set is compared, PPBBO diversity is better than the BBO one.

TABLE II
BEST RESULTS FOUND BY BOTH OPTIMIZATION APPROACHES

Index	BBO	PPBBO
Mean distance to the point (100,0) (efficiency, mass)	11.7828	11.6681
Mean spacing (f_1, f_2)	0.0651	0.0610

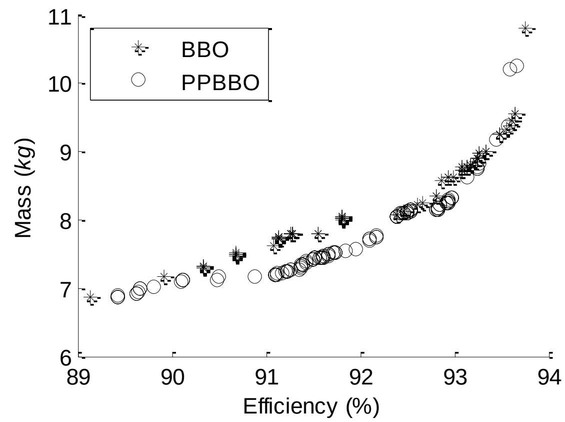

Fig. 3. Pareto set points of BBO and PPBBO approaches.

V. CONCLUSION

In this paper were evaluated two multi-objective bio-inspired approaches: BBO and PPBBO. The use of the biogeography combined with predator-prey concepts is promising and can be validated in other types of optimization problems.

Results for BBO and PPBBO techniques seem to be very close, but the concept of predator-prey allows BBO, i.e., PPBBO to reach a more representative Pareto set, because in the last case the diversity is better.

VI. REFERENCES

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