Biogeography–Based Optimization Applied to Wireless Communications Problems

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INTRODUCTION

The Evolutionary Algorithms (EAs) mimic behaviour of biological entities and they are inspired from Darwinian evolution in nature. The EAs have been extensively studied and applied to several real-world engineering problems. Biogeography-based optimization (BBO) (Simon, 2008) is a recently introduced evolutionary algorithm. BBO is based on mathematical models that describe how species migrate from one island to another, how new species arise, and how species become extinct. The way the problem solution is found is analogous to nature's way of distributing species. In the BBO approach there is a way of sharing information between solutions (Simon, 2008), similar to the other evolutionary algorithms such as GAs, DE, and PSO. This feature makes BBO suitable for the same types of problems that the other algorithms are used for, namely high-dimensional data. Additionally, BBO has some unique features, which are different from those found in the other evolutionary algorithms. For example, quite different from GAs, DE and PSO, the set of the BBO's solutions is maintained from one generation to the next and is improved using the migration model, where the emigration and immigration rates are determined by the fitness of each solution. These differences can make BBO outperform other algorithms (Simon, 2008). BBO has been applied successfully to several real world engineering problems (Ashrafinia, Pareek, Naeem, & Lee, 2011; Bhattacharya & Chattopadhyay, 2010; Boussaïd, Chatterjee, Siarry, & Ahmed-Nacer, 2011; S. K. Goudos et al., 2012; Jamuna & Swarup, 2011; Kankanala, Srivastava, Srivastava, & Schulz; Mandal, Bhattacharya, Tudu, & Chakraborty, 2011; Rathi, Agarwal, Sharma, & Jain, 2011; Silva, dos S Coelho, & Freire, 2010).

The purpose of this chapter is to briefly describe the BBO algorithm and present its application to antenna and wireless communications design problems. This chapter presents results from design cases that include patch antenna, linear antenna array, and a Partial Transmit Sequence (PTS) scheme for OFDM signals based on BBO. The chapter is supported with an adequate number of references. This chapter is subdivided into five sections. The "Background" Section presents the issues, problems, and trends with BBO. Then we briefly present the main BBO algorithm. In the next Section, we describe the design cases and present the numerical results. An outline of future research directions is provided in the following Section while in the "Conclusion" Section we conclude the chapter and discuss the advantages of using a BBO-based approach in the design and optimization of wireless systems and antennas. Finally, an "Additional Reading Section" gives a list of readings to provide the interested reader with useful sources in the field.

BACKGROUND

The mathematical models of Biogeography are based on the work of Robert MacArthur and Edward Wilson in the early 1960s. Using this model, they have been able to predict the number of species in a habitat. The habitat is an area that is geographically isolated from other habitats. The geographical areas that are well suited as

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residences for biological species are said to have a high habitat suitability index (HSI). Therefore, every habitat is characterized by the HSI which depends on factors like rainfall, diversity of vegetation, diversity of topographic features, land area, and temperature. Each of the features that characterize habitability is known as suitability index variables (SIV). The SIVs are the independent variables while HSI is the dependent variable.

Similar to the other evolutionary algorithms (EAs) such as Genetic Algorithms (GAs), Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC) optimization, in the BBO approach there is a way of sharing information between solutions (Simon, 2008). This feature makes BBO suitable for the same types of problems that the other algorithms are used for, namely high-dimensional data. Additionally, BBO has some unique features that are different from those found in the other evolutionary algorithms. For example, quite different from GAs, Ant Colony Optimization (ACO) and PSO, from one generation to the next the set of the BBO's solutions is maintained and improved using the migration model, where the emigration and immigration rates are determined by the fitness of each solution. BBO differs from PSO in the fact that PSO solutions do not change directly; the velocities change. The BBO solutions share directly their attributes using the migration models. The migration operator provides BBO with a good exploitation ability. These differences can make BBO outperform other algorithms (Ma, 2010; Ma, Simon, Fei, & Chen, 2013; Simon, 2008). It must be pointed out if PSO or ABC are constrained to discrete space then the next generation will not necessarily be discrete (Ma, et al., 2013). However, this is not true for BBO; if BBO is constrained to a discrete space then the next generation will also be discrete to the same space. As the authors in (Ma, et al., 2013) suggest this indicates that BBO could perform better than other EAs on combinatorial optimization problems, which makes BBO suitable for application to the PTS problem. The main computational cost of EAs is in the evaluation of the objective function. The BBO mechanism is simple, like that of PSO and ABC. Therefore, for most problems, the computational cost of BBO and other EAs will be the same since it will be dominated by objective function evaluation (Ma, 2010). More details about the BBO algorithm can be found in (Ma, et al., 2013; Simon, 2008).

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Therefore, a solution to a D-dimensional problem can be represented as a vector of SIV variables:

$$\left[SIV_1, SIV_2, \ldots SIV_D\right]$$

which is a habitat or island. The value of HSI of a habitat is the value of the objective function that corresponds to that solution and it is found by:

$$HSI = F\left(habitat\right) = F(SIV_1, SIV_2, \ldots SIV_D)$$

Habitats with a high HSI are good solutions of the objective function, while poor solutions are those habitats with a low HSI. The habitats with high HSI are those that have large population and high emigration rate μ. For these habitats, the immigration rate λ is low. The immigration and emigration rates are functions of the rank of the given candidate solution. The rank of the given candidate solution represents the number of species in a habitat. These are given by:

$$\mu_k = E\left(\frac{k}{S_{\max}}\right), \lambda_k = I\left(1 - \frac{k}{S_{\max}}\right)$$

here I is the maximum possible immigration rate, E is the maximum possible emigration rate, k is the rank of the given candidate solution, and $S_{\max}$ is the maximum number of species (e.g. population size). The rank of the given candidate solution or the number of species is obtained by sorting