Chapter 1

Application of Nature-Inspired Algorithms for the Solution of Complex Electromagnetic Problems

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ABSTRACT

In the last decade nature-inspired Optimizers such as genetic algorithms (GAs), particle swarm (PSO), ant colony (ACO), honey bees (HB), bacteria feeding (BFO), firefly (FF), bat algorithm (BTO), invasive weed (IWO) and others algorithms, has been successfully adopted as a powerful optimization tools in several areas of applied engineering, and in particular for the solution of complex electromagnetic problems. This chapter is aimed at presenting an overview of nature inspired optimization algorithms (NIOs) as applied to the solution of complex electromagnetic problems starting from the well-known genetic algorithms (GAs) up to recent collaborative algorithms based on smart swarms and inspired by swarm of insects, birds or flock of fishes. The focus of this chapter is on the use of different kind of natured inspired optimization algorithms for the solution of complex problems, in particular typical microwave design problems, in particular the design and microstrip antenna structures, the calibration of microwave systems and other interesting practical applications. Starting from a detailed classification and analysis of the most used nature inspired optimizers (NIOs) this chapter describes the not only the structures of each NIO but also the stochastic operators and the philosophy responsible for the correct evolution of the optimization process. Theoretical discussions concerned convergence issues, parameters sensitivity analysis and computational burden estimation are reported as well. Successively a brief review on how different research groups have applied or customized different NIOs approaches for the solution of complex practical electromagnetic problem ranging from industrial up to biomedical applications. It is worth noticed that the development of CAD tools based on NIOs could provide the engineers and designers with powerful tools that can be the solution to reduce the time to market.
of specific devices, (such as modern mobile phones, tablets and other portable devices) and keep the commercial predominance: since they do not require expert engineers and they can strongly reduce the computational time typical of the standard trial errors methodologies. Such useful automatic design tools based on NIOs have been the object of research since some decades and the importance of this subject is widely recognized. In order to apply a natured inspired algorithm, the problem is usually recast as a global optimization problem. Formulated in such a way, the problem can be efficiently handled by natured inspired optimizer by defining a suitable cost function (single or multi-objective) that represent the distance between the requirements and the obtained trial solution. The device under development can be analyzed with classical numerical methodologies such as FEM, FDTD, and MoM. As a common feature, these environments usually integrate an optimizer and a commercial numerical simulator. The chapter ends with open problems and discussion on future applications.

INTRODUCTION

Nature inspired optimization (NIO) algorithms has been successfully adopted for many years as power-ful optimization tools in several areas of applied engineering (P. H. King, 2006; James M. Whitacre et al. 2008; S. He, Q. H. Wu, & J. R. Saunders, 2009; M. D. Gregory, J. S. Petko, et al. 2010; Fang Liu, Leping Lin, et al. 2015). They are very effective to solve various complex problems because of their effectiveness, simplicity and flexibility. The goal of this chapter is to report the evolution of the most common NIOs, trying to provide their keys strength and weakness. Before the development of NIOs, all the available optimization algorithms were based on the estimation of the gradient or conjugate gradient (CG) (R. Ringlee, 1965; S. Mitter, L. S. Lasdon, & A. D. Waren, 1966; L. Lasdon, S. Mitter, & A. Waren, 1967; B. N. Pshenichny, & Y. M. Danilin, 1978; Z. Wu, 2001; Zhengwei Xu, Michael, & S. Zhdanov, 2015), of the cost function. The CGs are commonly known as deterministic algorithms because if they are launched several times with the same initialization they always lead to the same solution. This is due because the CG update equation estimate the new position at iteration k+1, considering the previous position at iteration k, plus the gradient of the cost function, which indicates the direction of movement in the n\textsuperscript{th} dimensional search space multiplied for a constant called step size \(t\). The main advantage of CG based is their convergence rate since they are able to reach a very good solution in few iterations. The application of a CG based algorithm requires the analytical knowledge of the cost function (for the estimation of the gradient), a good initialization point. The main drawback of CG based algorithms is that they can be easily trapped in local minima because in presence of a local minima the gradient is zero and this correspond keep the new position equal to the old one. The CG based algorithm are the best solution for quadratic cost function, unfortunately almost all scientific and engineering problems show non-quadratic cost function characterized by different local minima. The problem of local minima led to the development of a new class of algorithms able to avoid the problem of the local minima. The new family of algorithms inspired to natural behaviour belong the family of evolutionary algorithms and they family of stochastic algorithms. They are also called non-deterministic algorithm because if we run several time a stochastic algorithm considering always the same initialization point, the obtained results will be always different because these kind of algorithms use stochastic operators. The first developed NIO algorithm was the genetic algorithm (GA) an optimizer that mimic the process of natural selection (discovered by Charles Darwin). A direct evolution of the GAs aimed at improve the convergence rate is