Chapter 8

Adaptive Non-Uniform Particle Swarm Application to Plasmonic Design

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ABSTRACT

The metaheuristic approach has become an important tool for the optimization of design in engineering. In that way, its application to the development of the plasmonic based biosensor is apparent. Plasmonics represents a rapidly expanding interdisciplinary field with numerous transducers for physical, biological and medicine applications. Specific problems are related to this domain. The plasmonic structures design depends on a large number of parameters. Second, the way of their fabrication is complex and industrial aspects are in their infancy. In this study, the authors propose a non-uniform adapted Particle Swarm Optimization (PSO) for rapid resolution of plasmonic problem. The method is tested and compared to the standard PSO, the meta-PSO (Veenhuis, 2006) and the ANUHEM (Barchiesi, 2009). These approaches are applied to the specific problem of the optimization of Surface Plasmon Resonance (SPR) Biosensors design. Results show great efficiency of the introduced method.

INTRODUCTION

In plasmonics, the Surface Plasmon Resonance (SPR) based sensors have an increasing expansion since the success in the engineering control of nanofabrication (Hoaa, Kirk & Tabrizian, 2007). They became one of the most successful label-free and commercially developed optical sensors. This technique is currently employed in biomolecular engineering, drug design, monoclonal antibody characterization, virus-protein interaction, en-
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The fabrication process of the SPR biosensors-nanometer scale- is complex and costly. Moreover, specific problems are related to this domain. Therefore, the design optimization of SPR biosensors is of great interest although it has been rarely addressed (Barchiesi, 2009; Barchiesi, Kremer, Mai & Grosges, 2008a; Lecaruyer, Canva & Rolland 2006; Ekgasit, Thammacharoen & Knoll, 2005; Kolomenskii, Gershon & Schuessler, 1997). Therefore appropriate adjustments to the most successful optimization technique must be introduced to solve these problems.

The Particle Swarm Optimization (PSO) was first introduced by Kennedy and Eberhart in 1995 and imitates the swarm behaviour to search the globally best solution. In this method, particle moves using its own experience and collaboration with neighbor swarm particles. This technique attracted a high level of interest because of its encouraging results and was the subject of many improvements. A first set of improvements is related to the PSO parameters. We will be basically interested with this issue to introduce a new optimization algorithm as it will be fully reported in the section 2.3. A second set of improvements is related to testing different topologies for different problems. The main discussed issues (Kennedy & Mendes, 2002; Hu & Eberhart, 2002; Mendes, Kennedy, & Neves, 2004; Liang, Qin, Suganathan & Baskar, 2006) are:

- Whether to adopt GBEST (a global search technique for best position) or one of the LBEST (local) configurations.
- If the PSO with small or high neighborhood might perform better.
- The weight/influence of each particle on its neighbours.
- How to move if the collaboration and self experience part dictates displacements in opposite sides.

In this paper, we will introduce a new PSO algorithm—basically using adaptive PSO parameters with non-uniform law- and compare its efficiency with some other techniques while applied to the plasmonic problem. The second section will introduce SPR biosensor optimization problem and give the related fitness function and decision variables. The proposed optimization method as well as other methods used for the benchmarking will be presented in section 2. In the third section, numerical results will be reported and discussed. Finally, in the last section, some conclusions and perspectives will be drawn.

THE OPTIMIZATION PROBLEM OF SPR BIOSENSORS

The operating principle of the SPR biosensors is based on the shift of the position of mathematical poles. This mathematical issue is in fact related to a critical change of the interaction between light and matter/substrate that happens in presence of slight environment changes (especially the presence of substances to be detected by the sensor) (Barchiesi et al., 2008b; Kretschman & Raether, 1968). Basically, a sudden absorption of light by metal layer of the biosensor occurs, for a given incidence angle of the illumination, leading to a device with high sensitivity to any change in the surrounding biological environment (Leracuyer et al., 2006; Kolomenskii et al., 1997).

The problems encountered in plasmonics depend on complex parameters (characteristics of materials, \( n_i \) (\( i=1,\ldots,4 \)) in Figure 1) varying with the illumination condition (Homola, 1997). Moreover, in general case, they could be a function of more than ten parameters (Davy, Barchiesi, Spajer, & Courjon, 1999; Fikri, Grosges, & Barchiesi, 2003; Fikri, Grosges, & Barchiesi, 2004, Pagnot, Barchiesi, Labeke & Pieralli, 1997). Therefore, an appropriate optimization method should be introduced.
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