Introduction

1 Importance and topicality of the subject

Because of the real life interest in solving many optimization problems, it was developed a wide scientific literature on the optimization subject. Google Scholar reports for the term "optimization" about 4 millions scientific papers, from which about a million in the past ten years, which proves the importance and the topicality of the subject. In present, the optimizations are considered part of Math, Computer Science and Operational Research Science. No matter the field, improvement of a solution supposes solving of an optimization problem. All performant products are the result of an optimization action.

The optimization problems are classified in two major categories: without restrictions and with restrictions. These may be convex (with a single minimum) or not (with multiple local minimum). In the convex case, the objective function is smooth and differentiable, case that is exploited by the solving methods. In the non-convex case, the function is not smooth which makes the optimization problem far more difficult.

The solving methods for this kind of problems are classified in two major categories: deterministic and stochastic. The deterministic methods may be with or without gradient use or use of another higher order derivatives of the objective function. These methods can not solve problems with multiple local minima, because these incline to a local minimum. For determining global minimum are used different stochastic methods which apparently seem to chaotic explore the search space but these give the chance to the algorithm to find the global minimum. These methods are of metaheuristic type and do not guarantee to find the optimal solution, but find a pseudooptimal one. Most heuristics are inspired from nature and are classified in "single-solution" and "population based". The second class is suitable to parallelization.

In many cases, the optimization of electromagnetic devices is an optimization of their geometric dimensions and of the position and the values of the electromagnetic field sources such that some objectives are satisfied. The difficult part is made by the complexity of the objective function which has many local minima and the fact that the evaluation of the objective function implies numerical solving of an electromagnetic field problem which requires important computing resources like processor and memory.

The PSO (Particle Swarm Optimization) algorithms [Kennedy95] are iterative stochastic optimization methods, which use a population of candidate solutions which evolves in time. Those algorithms are independent of the problem to be solved and are appropriate to difficult optimization problems when the derivative of the objective function is unknown. The main problems of the classical PSO algorithm are a high probability to get stuck in a local minimum point and a large number of iterations needed to find the global solutions. This thesis contains innovative improved variants of PSO algorithms which will be described next.

The main disadvantage of stochastic methods is a large number of objective function evaluations, especially when the cost of objective function evaluation is significant. In this case, the running time of sequential implementation is too high, hence the need for algorithm parallelization. The technological evolution regarding transistor shrinking brought a limitation in the processors working frequency as a cause of the difficulty to extract the generated heat. The alternative is represented by parallel architectures grouped in multi-core clusters or GP-GPU devices which contain hundreds of cores if those are efficiently exploited by use of parallel algorithms.

2 Thesis structure

This thesis contains seven chapters and starts with an introduction which presents the importance and the topicality of the research subject and the thesis structure.

In the first chapter is presented the electromagnetic and multiphysic modeling technique developed in the Numerical Models Laboratory (LMN) which contains coceptual modeling, mathematical modeling, analytic-approximative modeling, numerical modeling, computational modeling, model reduction and model verification and validation.

Chapter two describes the addressed test problems: Loney's solenoid, TEAM22 benchmark problem and a problem from nondestructive electromagnetic testing. Those problems have different characteristics and this fact is usefull because in practice it is a great diversity of situations.

In the third chapter are presented the particle swarm optimization algorithms. There are presented the clasic PSO, Standard PSO, Discrete PSO, Intelligent PSO, Quantum PSO and variants.

In chapter four are presented systems and techniques of high performance computing. There are presented parallel programming models and are described architectures and GPU devices and the CUDA programming model.

Chapter five describes electromagnetic device optimization methods based on PSO algorithms which are applied to the test problems. There are presented innovative improved PSO based algorithms.

Chapter six presents HPC techniques applied for rapid evaluation of the electromagnetic optimization problems objective functions for the TEAM22 problem and the forward problem from nondestructive electromagnetic testing.

Chapter seven presents solutions based on optimization algorithms parallelization and describes the FPMB (full parallel minimum branching) configuration for parallelizing on GPU devices and the Pthreads parallelizing technique on multi-core processors. A comparison is made between the parallel implementations as time and results for the test problems.

Then is made a conclusion synthesis of the thesis and are related the main original contributions and is presented the list of papers published by the author.

The thesis ends with appendices which contain code sequences of the programs developed by the author.