ABSTRACT

SOFTWARE TOOLS FOR FINITE ELEMENT OPTIMIZATION IN MAGNETICS ON A GPU

By
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The design of magnetic devices requires optimization coupled with finite element analysis (FEA). This involves a massive computational load and requires a specialized mesh generator. It is therefore not practicable. This thesis therefore presents i) a parameterized iterative mesh generator for two-dimensional and three-dimensional finite element optimization; ii) fast and low memory finite element solvers using a graphics processing unit (GPU). In particular we introduce element by element finite element computations on a GPU with a speedup of 102 while some other method gives only 10; and iii) examine parallelizing such matrix computations on already parallelized genetic algorithm threads using new GPU architectures. The resulting system is reliable and yields solutions in practicable times with massive speedup. Example inverse optimization problems are presented. These software tools are written in C/C++ and CUDA C/C++. The system is shown to be applicable to the synthesizing of two-dimensional and three-dimensional electromagnetic devices and to non-destructive evaluation (NDE) problems.

Several finite element mesh generators exist in the public domain, some even based on a parametric device description. But for optimization we need a parametrically described mesh dynamically evolving through the iterations without user input. The few that exist are
commercial and their methodology is not known. In this thesis the mesh generator that we
describe is in open source code with parametric mesh generation that runs nonstop and
seamlessly through optimization iterations to convergence without user intervention. Such mesh
generators as do exist are rare, commercial and not easily available to researchers except at great
cost and never with the code to modify it to suit individual needs. Besides, the typical mesh
generator requires some man-machine interaction to define the points and boundary conditions
and does not work for nonstop optimization iterations. We take two regular open source mesh
generators, one for two-dimensional systems and the other for three-dimensional systems, and
write a script-based interface as open source to run nonstop for optimization. We then use it to
create an NDE system for an army ground vehicle’s hull defect characterization and use it
equally adaptively for machine design. A simple scheme of averaging neighbor heights gives us
a smooth geometry without having to use Bezier curves.

This thesis also points out using a literature survey issues in GPU computation which
result in erratic speedup and explain why in some instances GPU solutions are arithmetically a
slight improvement on CPU solutions.

Publications

Journals articles

1. **S. Sivasuthan**, V. U. Karthik, A. Rahunanthan, P. Jayakumar, Ravi Thyagarajan, Lalita
   Udpa and S.R.H. Hoole, “Addressing Memory and Speed Problems in Nondestructive Defect
   Characterization: Element-by-Element Processing on a GPU,” *Journal of Non-destructive
   Evaluation*, vol. 34(9), 2015. DOI: 10.1007/s10921-015-0282-z

2. S. Ratnajeevan H. Hoole, **Sivamayam Sivasuthan**, Victor U. Karthik and Paul R.P. Hoole,
   “Flip-teaching Engineering Optimization, Electromagnetic Product Design and Nondestructive
   Evaluation in a Semesters Course,” *Computer Applications in Engineering Education


Conferences


