Supercomputer Simulation of Radio-Frequency Hepatic Tumor Ablation

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The talk is in the field of large-scale computing in bio-medical engineering. A 3D voxel approach is used for finite element method (FEM) approximation of the involved partial differential equations. The discrete problem has hundreds of millions of degrees of freedom. The implementation of the computer model is done on supercomputer IBM Blue Gene/P.

We simulate the thermal and electrical processes, involved in the radio-frequency (RF) ablation procedure. RF ablation is a low invasive technique for the treatment of hepatic tumors, utilizing AC current to destroy the tumor cells by heating. The destruction of the cells occurs at temperatures of 45-50°C. The procedure is relatively safe, as it does not require open surgery. The surgeon places a RF probe inside the tumor and initiates RF current on it.

The mathematical model consists of two parts – electrical and thermal. The energy from the applied AC voltage is determined first, by solving the Laplace equation to find the potential distribution. After that, the electric field intensity and the current density are directly calculated. Finally, the heat transfer equation is solved to determine the temperature distribution. Heat loss due to blood perfusion is also accounted for.

The representation of the computational domain is based on a voxel mesh. Linear FEM in space is used for both partial differential equations. After the space discretization, the backward Euler scheme is used for the time stepping.

A parallel preconditioned conjugate gradient solver is used for the arising linear systems. As a preconditioner, we use BoomerAMG – a parallel algebraic multigrid implementation from the package Hypre, developed in LLNL, Livermore.

Parallel numerical tests run on the IBM Blue Gene/P massively parallel computer are presented. Some scalability issues are discussed.

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