Parallelisation of Finite Element Analysis for a Bone Remodelling Simulator on the White Rose Grid

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The bone remodelling simulation project team (Hull University Computer Science, Engineering and Medical Physics) have developed software (BMUSim) that simulates the net effect of bone remodelling activity of trabecular bone structures due to aging and bone diseases (e.g. osteoporosis and rheumatoid arthritis). This bone remodelling activity is influenced by the strain pattern within a loaded bone structure. As bone remodels, its structure changes which means the finite element analysis (FEA) calculation must be repeated several times during a simulation.

On a 2.5 GHz PC the FEA calculation for an iliac crest bone structure represented by a 220 voxel cube (i.e. 10 million voxels) took 46 hours. The FEA software was recoded as a parallel program using MPI to run on the Snowdon HPC cluster at the White Rose Grid. Rows of the stiffness matrix of the FEA problem are distributed between the CPU's. The FEA problem is solved using either the Jacobi or the Conjugate Gradient method. Using 64 CPUs of 32 compute server nodes the run time for the FEA calculation was reduced to 30 minutes. Interestingly a speed up of 80 was achieved and was due to more effective use of cache memory and reduced datasets of the distributed solution.

Subsequently the parallel FEA solver was run on the Eagle HPC cluster (72 CPUs) at the University of Hull. BMUSim (the bone remodelling simulator) runs on a separate Windows PC and communicates with the HPC cluster to solve the FEA problem several times whilst simulating a bone remodelling scenario.

Parallelisation of the FEA calculation has allowed the project team to investigate larger bone remodelling scenarios.

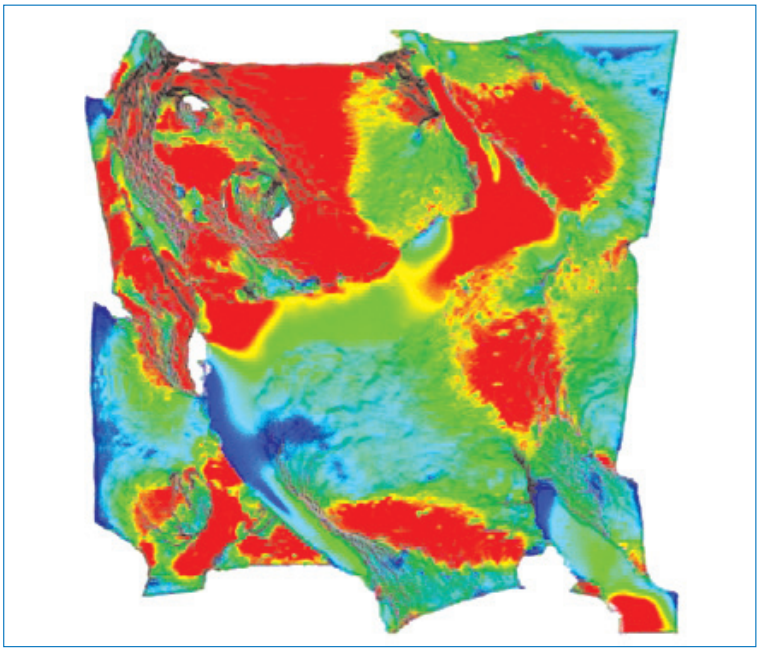

Figure 1: Trabecular bone of ileac crest with strain pattern mapped to surface of bone

A bone remodelling simulation of a bone structure of over 500 voxel cube (i.e 125 million voxels) can now be achieved over a weekend using 64 CPUs. This would have taken over 120 days on a PC workstation.

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Further Information

Contact:
Prof R Philips,
University of Hull Computer Science,
email: r.phillips@dcs.hull.ac.uk

The project's web pages are at:
http://www.eng.hull.ac.uk/research/medical/modelling_osteoporosis.htm