Bone Structure Analysis on Multiple GPGPUs

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Osteoporosis is a disease that affects a growing number of people by increasing the fragility of their bones. The lifetime risk for osteoporotic fractures in women is estimated close to 40%, for men risk is 13%. Since global parameters like bone density do not admit to predict the fracture risk, patients have to be treated in a more individual way.

Today's approach consists of combining 3D high-resolution CT scans of individual bones with a micro-finite element analysis. To improve the understanding of bone, large scale computer simulations are applied. In recent years we have developed a fast, scalable and memory efficient solver for such problems called ParOSol. The equations of linear elasticity in pure displacement formulation are discretized by the finite element method. The resulting linear system of equations is solved by the conjugate gradient algorithm with a multigrid preconditioner. The solver is matrix free on all grid levels. Note that the principle obstacle in this problem is the very complicated computational domain entailed by osteoporotic bones. We have ported the solver to GPGPUs to profit from their exorbitant compute capabilities. We discuss how we modified the CPU code to run successfully on multi-GPGPUs. We present the implementation of ParOSol on Tödi (todi.cscs.ch), a machine at the Swiss Supercomputing Centre CSCS.

The code shows perfect weak scaling up to 256 GPGPUs. The largest problem solved on the machine contained about 8 billion voxel elements corresponding to about 25 billion degrees of freedom. Compared to the pure MPI code run on the 16-core nodes of Tödi we observe speedups of the MPI-Cuda code beyond five.

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