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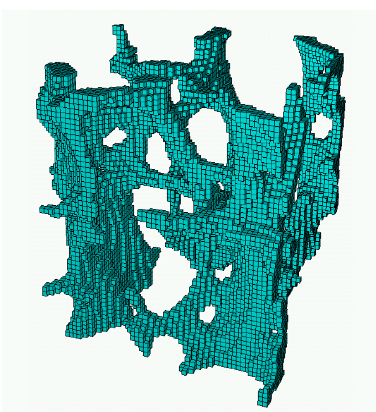
Bone structure analysis with GPGPUs – Part 2

Proposal for a bachelor / master thesis

Introduction

The aging of the human population made the number of bone fractures due to osteoporosis increase considerably. In Switzerland, the risk for an osteoporotic fracture in women above 50 years is about 50%, for men the risk is about 20%[1]. Not surprisingly, research concerning osteoporosis plays a prominent role in health science. Often, large scale computer simulations are conducted to improve the understanding of the bone structure and bone strength [1]. These simulations are based on voxel models of the bone that are obtained by high-resolution CT scans. The voxel model constitutes a structure that is investigated for its elastic properties. The structures are composed by millions of tiny cubes (voxels), see the image on the left. Our simulations are based on finite element discretizations for linear or non-linear elasticity and lead to very large linear or non-linear systems of equations with hundreds of millions or even billions of unknowns [1–5].



The typically symmetric positive definite linear systems are solved by the preconditioned conjugate gradient algorithm on large parallel computers [6].

In recent years we have developed a computer program called ParFE that solves these problems very efficiently, in terms of computing time and in terms of memory space [2,3,7]. More recently, we have developed a code named ParOSol [8] that is faster than ParFE and much more memory-efficient [4,5]. This code has recently been ported to NVIDIA Kepler graphics processing units using CUDA [9,10].

Description of the task

The task of this work is to analyse the performance of the CUDA code and suggest and implement improvements. The investigation is restrict to what we call “offset approach”. In this approach the most important kernel is a 24×24 dense matrix-vector multiplication. This leads to an arithmetic intensity that seems high enough to get close to peak performance of the GPU. This is however not the case. We only obtain about 10% of the peak performance. Therefore, the data movements in that kernel between main memory, shared memory and registers have to be analyzed carefully.

In a first step, the algorithm shall be investigated on a single GPU available in our group. In a second step, the modifications have to be incorporated in CUDA-ParOSol. The target machine is Tödi or Piz Daint at CSCS [2].

[1] See http://www.osteoswiss.ch
[2] http://www.cscs.ch

Requirements

- Good knowledge in C++ and parallel computing.
- Some knowledge of finite elements is very useful.
- Willingness to work in an interdisciplinary environment.

Deliverables

The work is to be documented in a short and concise thesis (LaTeX, PDF). It must be written such that it is intelligible to a fellow-student.

The code should be written as clean as possible. It must be complemented by a short user's guide.

Presentation

At the end of the thesis, the work is to be presented by a talk in the group seminar. The date of the talk will be determined later.

Contact

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Literatur

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