Technology Strategy Board
Driving Innovation

Knowledge Transfer Network

Industrial Mathematics

On the fast track

USING A GRAPHICS PROCESSING UNIT IN OILFIELD RESERVOIR SIMULATION

Roxar / Bournemouth University

The need

Graphics Processing Units (GPUs) were initially developed for graphics applications. Due to the GPU's high computational performance there has been much interest in using them in the fields of numerical simulation and solving scientific problems.

GPUs have the potential to give substantial performance improvements for data-intensive calculations and offer tremendous opportunities in many high performance computing applications.

This aim of this project was to evaluate the use of GPUs to accelerate the calculation of flow in an oilfield reservoir.

The outcomes

A benchmark result with Diagonal Matrix Representation (DIA) has shown that the GPU is 4 times faster than the latest multi-core CPU system.

	Nehalem Xeon X5560 2.80 GHz x 2 24 GB RAM	GPU GTX 295 (using single GPU)
1 Core	14.7 ms	1.12 ms
8 Core	4.4 ms	

Table 1: DIA Vector Multiplication.

The results have shown that a single GPU can run significantly faster than multiple high-end CPUs. However, attaining good performance is highly dependent on the particulars of the memory layout of data. Furthermore, GPU performance is much more sensitive than the CPU to the implementation of the algorithm.

The internship has enabled Roxar to evaluate the value and cost of development to support GPUs in its applications. The work has given a better understanding of the link between numerical mathematics and how it is mapped to computer hardware.

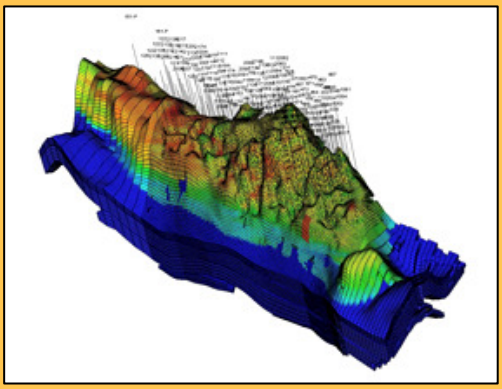
Finally, the intern has been exposed to problems outside of his academic field and the issues in developing commercial products.

"Ehtzaz brought the expertise to answer many questions we had about using a graphics card for numerical processing. It has been very helpful to have a keen and enthusiastic person to work on this complex problem."

Richard Hammersley
Roxar

Technical summary

The flow is calculated as the solution of a large set of non-linear equations. This is reduced to solving a system of sparse linear equations using Newton-Raphson iteration. The use of Newton-Raphson iteration for solving sparse linear equations is a standard numerical technique used in many fields.



In the domain of oilfield reservoir simulation the bulk of computational time is spent solving the linear equations.

The aim of the project was to accelerate the solution of sparse linear systems of equations using GPUs. A key component is sparse matrix vector multiplication. This is limited by memory bandwidth; a typical high-end CPU chip has a memory bandwidth of about 30GB/s. A typical high-end GPU has a memory bandwidth of about 100GB/s. We would expect a significant improvement in performance from the GPU as compared to a CPU. Indications suggest future GPUs will expand memory bandwidth faster than CPUs.

In this project, we have implemented and evaluated sparse matrix representations. In the case of coupled linear equations we also tested block and strip implementations of the sparse matrix. The basic representation was then used in a block tri diagonal solver on the GPU. This required taking an existing C++ algorithm implemented on the CPU and translating to the GPU programming language CUDA.

Our approach was to benchmark an existing MPI parallel C++ application using both single core and all 8 cores of a high-end CPU based system. These results were then compared with results using the latest NVIDIA GPUs.

"I had a wonderful internship experience with Roxar. I have learned a new skill, practical knowledge of applied mathematics, and its application in real-time simulations. I will use this expertise in my future PhD work."

Ehtzaz Chaudhry
Bournemouth University

"This internship provided an excellent opportunity for the PhD student to get involved in an industrial project, apply his knowledge and skills to tackle a practical industrial problem and obtain useful experience of working in industry which will be helpful for his PhD work."

Lihua You
Bournemouth University

This project was part of the programme of industrial mathematics internships managed by the Knowledge Transfer Network (KTN) for Industrial Mathematics. The KTN works to exploit mathematics as an engine for innovation. It is supported by the Technology Strategy Board, in its role as the UK's national innovation agency, and the Engineering and Physical Sciences Research Council, in its role as the main UK government agency for funding research and training in engineering and the physical sciences.

EPSRC
Engineering and Physical Sciences Research Council

Project Details

Partners
Roxar
Bournemouth University

Project investment
£10,000

Intern
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