28. Predicting the earth's climate with Graphics Processing Units

In order to predict the earth's climate, we need to understand the interaction between the atmosphere (air) and the oceans (water). Only at a resolution smaller than two kilometres essential physical phenomena such as ocean eddies are resolved in the ocean models. We develop ways in which climate modellers can use the enormous computing power that they need for high-resolution and long-running modelling. As high-resolution climate models require great computational power, we use Graphics Processing Units (GPUs) to perform the computations.
Our demo consists of two parts. The first part is a short movie that shows the results of our ICT-research: performance models for overlapping GPU-computations with CPU-GPU communication. The second part is an interactive visualization of the Parallel Ocean Program, a scientific research program to model the oceans. Our performance models have been applied in this research program.

ICT science question

How to optimize data transfers between hosts and GPUs?
Real programs contain dozens of kernels, i.e. small computer programs that manage input-output requests. On GPUs, the computational time of these individual kernels can often be optimized and reduced to virtually zero. At that point the transfer times between all these GPU kernels become the next bottleneck. The problem is that there are many different mechanisms for these transfers and the best mechanism depends on details of the algorithm.
To solve this problem, we have developed a generic performance model that greatly helps in deciding which mechanism is optimal, thus avoiding the need to implement and measure all alternatives.

Application

We apply the results of our ICT research in the Parallel Ocean Program (POP), a component of the coupled Climate Earth System Model, maintained by NCAR (Boulder, CO, USA). Our scientific partner in The Netherlands is prof. Henk Dijkstra from the University of Utrecht.

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COMMIT/ project
IV-e e-Infrastructure Virtualization for e-Science Applications

Alternative Application

The results of our research are being applied to a number of other domains, in particular in applications where CPU-GPU data transfers form a significant bottleneck.
One example is the problem of Radio Frequency Interference mitigation in Radio Astronomy. Another example is deep analysis of data obtained from crime scenes, in particular image and video data. In this latter domain of forensic analysis we have set up a collaboration with the Netherlands Forensics Institute (NFI).

Nice to know

The GPU work was nominated for best paper at IEEE/ACM CCGrid'2014 (May 2014, Chicago, USA) from a total of 283 submissions. So, it belonged to the top one percent.

The work with Utrecht and several other international partners was winner of the Enlighten Your Research - Global 2014 Award (November 2013, Denver, CO, USA).

To understand the impact of climate change, researchers need high-resolution simulations, which require so much computational power that we use Graphics Processing Units to perform these computations.

This project presents a performance model that allows application developers to identify what implementation strategy to use when integrating Graphics Processing Units into applications.

The ability to efficiently use Graphics Processing Units will allow us to perform Climate simulations at extreme resolutions, where essential physical phenomena are fully resolved in the models.

Our work on performance models for overlapping CPU-GPU data transfers opens up several avenues for future work, while our work on climate models will lead to more insights in future climate.

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