Development of Desktop Computing Applications and Engineering Tools on GPUs

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Introduction and Background

GPULab - A competence center and laboratory for research and collaboration within academia and partners in industry has been established in 2008 at section for Scientific Computing, DTU informatics, Technical University of Denmark. In GPULab we focus on the utilization of Graphics Processing Units (GPUs) for high-performance computing applications and software tools in science and engineering, inverse problems, visualization, imaging, dynamic optimization. The goals are to contribute to the development of new state-of-the-art mathematical models and algorithms for maximum throughout performance, improved performance profiling tools and assimilation of results to academic and industrial partners in our network. Our approaches calls for multi-disciplinary skills and understanding of hardware, software development, profiling tools and tuning techniques, analytical methods for analysis and development of new approaches, together with expert knowledge in specific application areas within science and engineering. We anticipate that our research in a near future will bring new algorithms and insight in engineering and science applications targeting practical engineering problems.

Fast Simulation of Unsteady Nonlinear Water Waves

For analysis and prediction of unsteady dispersive nonlinear water waves over uneven bottoms from shallow to deep water and for wave-structure interactions in ocean and offshore engineering it is important to have fast simulations tools. In a current project, we focus on designing new or improved algorithms that are massively parallel and can achieve a high effective arithmetic throughput in simulations based on state-of-the-art algorithms in computational fluid dynamics problems for ocean and offshore engineering. This will enable opportunity for accurate and fast analysis and prediction of flow evolution and kinematics, e.g. in large areas, over long times and for doing fast parameter studies based on the efficient solution of many problems.

Kernel based searchlight Heuristic for realtime fMRI

A novel searchlight heuristic that yields similar results to resampling based searchlight approaches has been developed. The reduced computational complexity of the suggested heuristic enables searchlight approaches to be applied in a real-time setting preventing the need for functional localizer scans. The suggested heuristic also enables the use of dynamic searchlight procedures capable of adapting to changes in the subjects strategy, performance or brain state during the experiment. Finally, the absence of data dependencies between distinct searchlight regions and the low memory footprint, makes the heuristic highly suitable for modern multi core architectures.

GPU FFT and Convolution

The GPU is extremely efficient at computing the Discrete Fourier Transform. Because of its roots in graphics, it is particularly well-suited for working with 4-vectors. This means that two DFTs in parallel is a very good idea (two complex numbers in each 4-vector). We implement two parallel FFTs in GLSL using the classic Cooley-Tukey algorithm, which is now available in the CUDA library called CUFFT. Using the GPU FFT implementation, we can easily implement convolution on the GPU. The two parallel FFTs become a great advantage since we can compute the FFT of corresponding color bands in parallel and multiply them immediately after. We need nine 2D FFTs to convolve two RGB images.