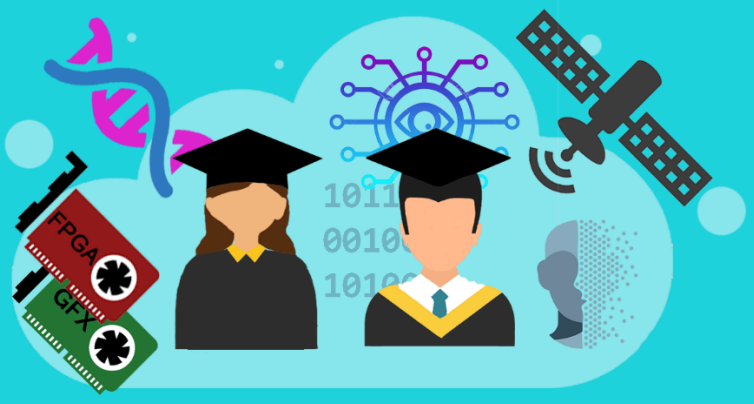
Diploma Thesis

Microproccessors and Digital Systems Laboratory



Sparsity and Loop Optimizations in Computational Fluid Dynamics

Computational Fluid Dynamics (CFD) is widely used in industries like aerospace, automotive, and civil engineering to simulate fluid flow, heat transfer, and turbulence It allows engineers to optimize designs through computational simulations, eliminating the need for costly and time-consuming physical experiments

SOD2D is a Fortran-based, GPU-accelerated tool for simulating fluid dynamics. Similarly, OpenFOAM, a C++ based, widely-used open-source Computational Fluid Dynamics (CFD) platform, also handles large-scale fluid dynamics simulations utilizing different solver algorithms and pre-/post- processing tools. By integrating advanced loop manipulation and matrix representation optimization techniques into both SOD2D and OpenFOAM, the efficiency of simulations in terms of memory footprint and processing time can be significantly improved.

This thesis will explore how to exploit matrix sparsity—high occurrence of zero values in matrices—and compare different methods of compressing sparse matrices, from simpler ones such as Compressed Sparse Row (CSR), Coordinate List (COO), and Ellpack (ELL), to more advanced ones such as adaptive sparse tiling. **The goal is to evaluate how these compression formats impact memory efficiency and computational performance in the aforementioned CFD frameworks**, while maintaining simulation accuracy. By studying these techniques, the research will contribute to optimizing large-scale fluid dynamics simulations on GPUs.

PREREQUISITES:

Familiarity with: Python, Fortran.

Desirable qualifications: OpenACC, CUDA, Bash scripting.

RELATED MATERIAL:

https://www.sciencedirect.com/science/article/pii/S0010465523004125,

https://www.openfoam.com/,

https://dl.acm.org/doi/10.1145/3293883.3295712

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