EC7207 - High Performance Computing

Project proposal

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Reg No : EG/2020/3945

Title : Comparing Serial, OpenMP, CUDA, and Hybrid Methods for Solving the Heat Equation

Project Proposal

The heat equation is a fundamental partial differential equation used to model how heat diffuses through a material over time. Its standard form is:

$$\frac{\partial u}{\partial t} = \alpha \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right)$$

where u is temperature, t is time, x and y are spatial coordinates, and α is the thermal diffusivity constant. Numerically solving the heat equation for large grids is computationally demanding, making it an ideal candidate for parallel computing. This project aims to implement and compare four approaches—serial, OpenMP, CUDA, and a hybrid OpenMP+CUDA method—to determine the most effective strategy for different problem sizes and hardware setups.

Objectives

- Develop a baseline serial solver for the heat equation to ensure correctness and provide a reference for measuring speedup.
- Implement an OpenMP-based parallel solver to utilize multi-core CPU architectures.
- Develop a CUDA-based solver to leverage the massive parallelism of modern GPUs.
- Create a hybrid OpenMP+CUDA solver that combines both CPU and GPU resources for optimal performance.
- Compare all approaches in terms of execution time, scalability, and efficiency across varying grid sizes.

Expected Outcomes

- **Performance Trends:**
    - OpenMP is expected to perform best on small to medium grids using multi-core CPUs.
    - CUDA should provide the greatest speedup for large-scale problems on systems with compatible GPUs.
    - The hybrid approach is anticipated to deliver optimal performance on systems equipped with both powerful CPUs and GPUs.
    - The serial implementation will serve as a reference for validating results and measuring speedup.
- **Practical Insights:**
  The project will produce guidelines for selecting the most suitable parallelization strategy based on problem size and hardware availability. These findings will be valuable for computational scientists and engineers working on similar numerical problems.