

RUNNING PLASCOM2 ON BLUE WATERS WITH OPENMP OFFLOADING

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EXECUTIVE SUMMARY

Heterogeneous systems consisting of CPU+GPU on a single node (such as Blue Waters' XK nodes) are becoming more common. Programming effectively for such systems is a difficult challenge, especially for applications that were not developed to support them from the ground up. In this context, OpenMP has recently emerged as an interesting solution, with recent versions (≥ 4.5) permitting offloading capabilities in existing code. We added OpenMP offloading to PlasCom2, a multiphysics simulation application, with the HybridOMP framework. HybridOMP enables concurrent execution of application code on CPUs and GPUs, resulting in efficient resource usage and high-performance portability. Performance results on Blue Waters show gains of 2.2x on a single XK7 node.

RESEARCH CHALLENGE

Programming heterogeneous systems is a challenging task, as few programming models support executing code on accelerator devices, leading to the use of specialized solutions such as CUDA, OpenCL, Legion, or Kokkos. Such specialized languages have the advantage of being able to provide the best performance in many cases, as they can often offer support for special device features and offer good code generation for specific device types. However, existing application code often can not be reused and must be rewritten in a new language. Code is often not portable between devices (for example, between CPUs and GPUs), such that various devices may require different implementations, leading to duplicated code and an increased difficulty of code maintenance.

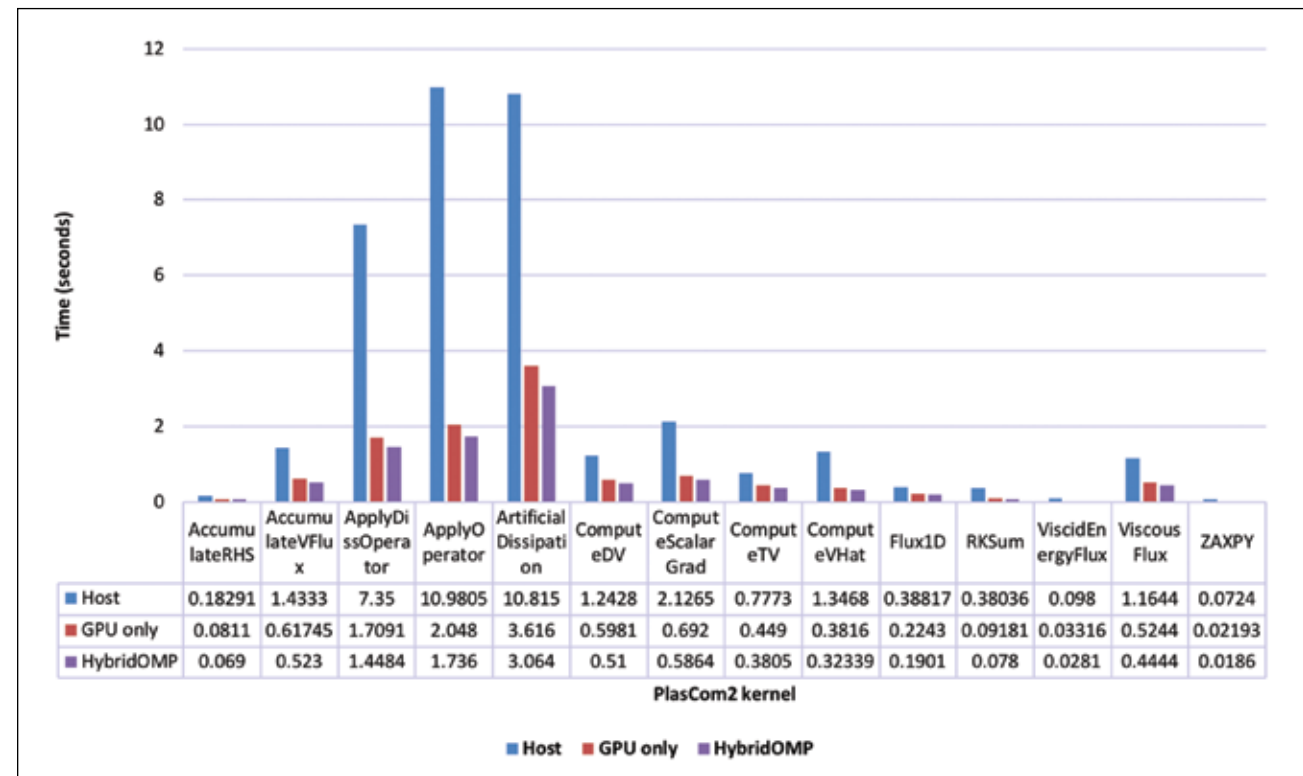


Figure 1: Single-node results of PlasCom2 kernels on the Blue Waters system.

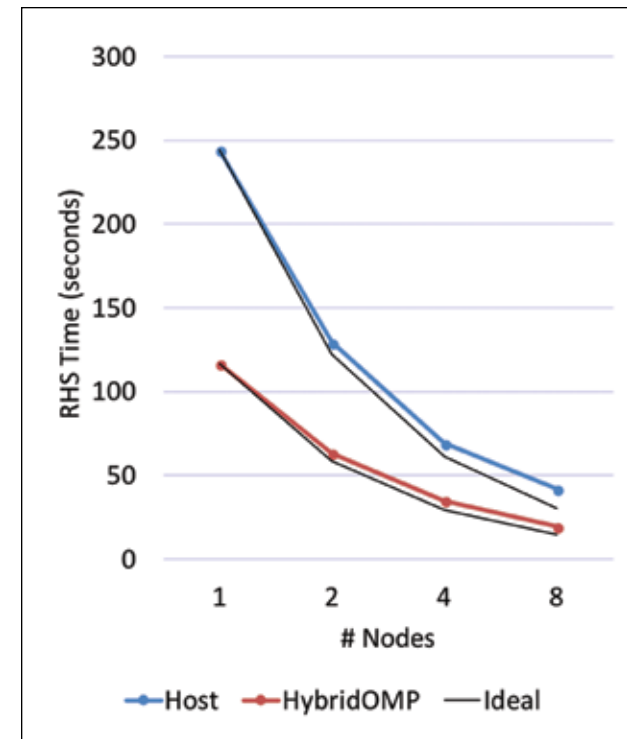


Figure 2: Scaling results of PlasCom2 on the Blue Waters system.

node. Compared to running only on the GPU, performance from heterogeneous execution was improved by 10%. Some of the computationally intensive kernels of PlasCom2 showed a speedup of 5x (Fig. 1). These gains remained similar when performing a strong scaling experiment on multiple nodes (Fig. 2). OpenMP offloading and HybridOMP show that existing codes can be enabled to run on heterogeneous systems with a low number of changes and high performance efficiency.

WHY BLUE WATERS

Blue Waters was essential to the research by providing a stable, high-performance platform with easy access to modern accelerators. HybridOMP and its integration into PlasCom2 could be developed directly on Blue Waters to evaluate and compare different implementation possibilities on a real system.

For PlasCom2, we needed an approach could use the existing code (C++ and FORTRAN) on several types of accelerators without having separate implementations for different device types. Furthermore, we wanted to be able to support different hardware and software environments, and run concurrently on both the host and offloading devices in order to use all available computing resources efficiently.

METHODS & CODES

Based on the offloading support available in recent OpenMP versions (≥ 4.5), we developed HybridOMP, which is a library to support concurrent execution on host and accelerator devices. For PlasCom2, HybridOMP measures the relative performance of the host and accelerator at startup and determines the best work distribution based on these data. During execution, HybridOMP handles the data movement between host and offloading device, as well as the actual code execution. HybridOMP requires an OpenMP 4.5 compiler and runtime but has no other dependencies.

RESULTS & IMPACT

OpenMP offloading enables simple and efficient execution of a single code base on different types of devices, with minimal changes to existing code. HybridOMP builds on top of OpenMP offloading to add support for fully heterogeneous execution; that is, running parts of the problem concurrently on different device types. Using HybridOMP with PlasCom2 resulted in a speedup of 2.2x compared to CPU-only execution on a Blue Waters XK7