KokkACC: Enhancing Kokkos with OpenACC

Pedro Valero-Lara, Seyong Lee, Marc Gonzalez-Tallada, Joel Denny, and Jeffrey S. Vetter

Advanced Computing Systems Research Section, Programming System Group

2022 International Conference for High Performance Computing, Networking, Storage, and Analysis (SC’22)

Kokkos Programing Model & KokkACC Implementation

MOTIVATION

Improve programming productivity:
- OpenACC codes are simpler to implement and maintain than other codes, such as CUDA, HIP, OpenCL, etc.
- Both (Kokkos and OpenACC) aim to be architecture agnostic, which make both models very similar and facilitate the implementation of the Kokkos features using OpenACC.
- Portable back-end. OpenACC model can target different architectures.
- Use OpenACC features to complement Kokkos features to improve performance on existing applications.
- Simplify the porting of OpenACC applications to Kokkos.

ATOMIC OPERATIONS & MEMORY

Kokkos atomic operations can be implemented by using OpenACC annotations.

- Kokkos::malloc (acc_malloc),
- Kokkos::free (acc_free) and
- Kokkos::view are used to represent user data.
- Kokkos::deep_copy (acc_memcpy_[to/from]_device) is used for memory transfers.

DESCRIPTIVE (OPENACC) VS PRESCRIPTIVE (CUDA)

OpenACC faster than CUDA?

Next, we highlight why it is possible to provide competitive or even better performance using a high-level and high programming productivity descriptive (pragma-based) model (OpenACC) than using a low-level prescriptive (device-specific) model (CUDA) for C++ Metaprogramming solutions (Kokkos).

- C++ Metaprogramming solutions, like Kokkos, rely on C++ lambdas. C++ lambdas are defined by application programmers and can express any operation.
- Device-specific solutions like CUDA weren’t designed to work at lambda level originally. CUDA Kokkos back-end relies on CUDA developers, who don’t know which operations will be computed by GPU kernels, but they must take decisions about size of CUDA blocks, memory usage, synchronization, etc. This makes the optimization of these solutions extremely difficult or even impossible.
- OpenACC backend relies on compiler, which can take better decisions depending on the operations defined by C++ lambdas and application developers.

Performance Analysis

PLATFORM

- ORNL SUMMIT
  - 1x NVIDIA Volta V100 GPU (16 GB)
  - CUDA back-end (CUDA 11.0.3)
  - OpenMP Target back-end (LLVM 15.0.0 git)
  - OpenACC back-end (NVHPC 21.3)

MINI-BENCHMARKS

- ATOMIC OPERATIONS & MEMORY
- DESCRIPTIVE (OPENACC) VS PRESCRIPTIVE (CUDA)
- CONCLUSIONS & FUTURE EFFORTS

Hierarchical Parallelism

Multi-Dimensional

CONCLUSIONS & FUTURE EFFORTS

OpenACC vs CUDA:
- Competitive performance for Single Range.
- Better performance for Multi-Dimensional.
- Competitive performance for Hierarchical Parallelism parallel_for and worse performance for parallel_reduce.
- Competitive (lulesh) and better performance (miniFE) on mini-apps.

OpenACC vs OpenMP Target:
- Better performance in most of the cases tested.

KOKKACC is aligned with other important efforts:
- Analysis, codesign and development of the OpenACC capacity for C++.
- Enhancing C++ (for HPC) using the capacity of OpenACC.
- Design of new OpenACC capabilities.

Future Efforts:
- Implement future/current Kokkos features in OpenACC back-end parallel_scan, tasking, etc.
- Explore novel optimizations

REPOSITORY & CONTACTS

https://github.com/ORNL/kokkos-ornl/tree/openacc
- Pedro Valero-Lara, valerolarap@ornl.gov
- Seyong Lee, lees2@ornl.gov
- Marc Gonzalez-Tallada, gonzaleztalma@ornl.gov
- Joel Denny, dennyje@ornl.gov
- Jeffrey S. Vetter, vetter@ornl.gov

ORNL SUMMIT
- 1x NVIDIA Volta V100 GPU (16 GB)
- CUDA back-end (CUDA 11.0.3)
- OpenMP Target back-end (LLVM 15.0.0 git)
- OpenACC back-end (NVHPC 21.3)