Porting Applications to HIP

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Agenda

1. Porting applications to the HIP API
2. Code Conversion Tools
3. Portable HIP Build System
4. Other porting paths
5. Hipify example – Pennant mini-app
6. Questions
Porting applications to the HIP API
Ported in an Afternoon
HACC
Cosmology

Ported in a Single Day
SPECFEM3D
Seismology

Ported in 21 Days
QUDA
Quantum Physics

Ported in a Couple of Days
CHOLLA
Astrophysics
What is HIP?

AMD’s Heterogeneous-compute Interface for Portability, or HIP, is a C++ runtime API and kernel language that allows developers to create portable applications that can run on AMD’s accelerators as well as CUDA devices.

HIP:
- Is open-source
- Provides an API for an application to leverage GPU acceleration for both AMD and CUDA devices
- Syntactically similar to CUDA. Most CUDA API calls can be converted in place: cuda -> hip
- Supports a strong subset of CUDA runtime functionality
Code Conversion Tools
EXTEND YOUR APPLICATION PLATFORM SUPPORT BY CONVERTING CUDA® CODE

Code Conversion Tools

EXTEND YOUR APPLICATION
PLATFORM SUPPORT BY
CONVERTING CUDA® CODE

Single source
Maintain portability
Maintain performance

Hipify-perl
- Easiest to use; point at a directory and it will hipify CUDA code
- Very simple string replacement technique; may require manual post-processing
- It replaces cuda with hip, sed -e 's/cuda/hip/g', (e.g., cudaMemcpy becomes hipMemcpy)
- Recommended for quick scans of projects
- It will not translate if it does not recognize a CUDA call and it will report it
- Does not check for correctness

Hipify-clang
- More robust translation of the code
- Checks for correctness
- Checks all files during translation
- Generates warnings and assistance for additional analysis
- High quality translation, particularly for cases where the user is familiar with the make system

August 28th, 2023

HIP Lecture Series
Hipify tools

Individual file tools
- hipify-perl
- hipify-clang

Recursive directory tools
- hipconvertinplace.sh
- hipconvertinplace-perl.sh
- hipexamine.sh
- hipexamine-perl.sh

The perl® scripts are a set and the shell/clang tools are a set. The directory-based tools basically call the base tools, hipify-perl and hipify-clang, respectively.
Hipify-perl

- It is located in $HIP/bin/ (\texttt{export PATH=$PATH:[MYHIP]/bin})
- Command line tool: \texttt{hipify-perl foo.cu > new_foo.cpp}
- Compile: \texttt{hipcc new_foo.cpp}
- How does this work in practice?
  - Hipify source code
  - Check it in to your favorite version control
  - Try to build
  - Manually work on the rest
Hipify-clang

- Build from source
- hipify-clang has unit tests using LLVM™ lit/FileCheck (44 tests)
- Hipification requires same headers that would be needed to compile it with clang:
  - ./hipify-clang foo.cu -I /usr/local/cuda-8.0/samples/common/inc

https://github.com/ROCm-Developer-Tools/HIPIFY/blob/master/README.md
Recursive directory-based tools

hipifyexamine.sh and hipifyexamine-perl.sh

- hipifyexamine-perl.sh recursively runs hipify-perl with the -no-output -print-stats options (-examine option is a shorthand for -no-output -print-stats options).

hipifyconvertinplace.sh and hipifyconvertinplace-perl.sh

- hipifyexamine-perl.sh recursively runs hipify-perl with the -inplace -print-stats options.

Let’s show the convert script to understand what they do.
Source code for hipconvertinplace-perl.sh

```bash
#!/bin/bash

usage: hipconvertinplace-perl.sh DIRNAME [hipify-perl options]

hipify "inplace" all code files in specified directory.
# This can be quite handy when dealing with an existing CUDA code base since the script
# preserves the existing directory structure.

# For each code file, this script will:
# - If ".prehip" file does not exist, copy the original code to a new file with extension ".prehip". Then hipify the code file.
# - If ".prehip" file exists, this is used as input to hipify.
# (this is useful for testing improvements to the hipify-perl toolset).

SCRIPT_DIR=`dirname $0`
PRIV_SCRIPT_DIR=`$SCRIPT_DIR/../libexec/hipify`
SEARCH_DIR=$1
shift
$SCRIPT_DIR/hipify-perl -inplace -print-stats "$@" "$PRIV_SCRIPT_DIR/findcode.sh $SEARCH_DIR"
```

Calls the findcode.sh script which recursively looks for files with the extensions seen below.

```bash
#!/bin/bash

SEARCH_DIRS="$@

find $SEARCH_DIRS -name '*.cu' -o -name '*.C'
find $SEARCH_DIRS -name '*.cpp' -o -name '*.CXX' -o -name '*.c' -o -name '*.cc'
find $SEARCH_DIRS -name '*.CPP' -o -name '*.CXX' -o -name '*.C' -o -name '*.CC'
find $SEARCH_DIRS -name '*.cuh' -o -name '*.CUH'
find $SEARCH_DIRS -name '*.h' -o -name '*.hpp' -o -name '*.inc' -o -name '*.inl' -o -name '*.hxx' -o -name '*.hdl'
find $SEARCH_DIRS -name '*.H' -o -name '*.HPP' -o -name '*.INC' -o -name '*.INL' -o -name '*.HXX' -o -name '*.HDL'
```
Gotchas

- Hipify tools are not running your application, or checking correctness
- Code relying on specific Nvidia hardware aspects (e.g., warp size == 32) may need attention after conversion
- Certain functions may not have a correspondent hip version (e.g., __shfl_down_sync – hint: use __shfl_down instead)
- Hipifying can’t handle inline PTX assembly
  - Can either use inline GCN ISA, or convert it to HIP
- Hipify-perl and hipify-clang can both convert library calls
- None of the tools convert your build system script such as CMAKE or whatever else you use. The user is responsible to find the appropriate flags and paths to build the new converted HIP code.
What to look for when porting:

- Inline PTX assembly
- CUDA Intrinsics
- Hardcoded dependencies on warp size, or shared memory size
  - Grep for "32" just in case
  - Do not hardcode the warpsize! Rely on warpSize device definition, #define WARPSIZE size, or props.warpSize from host
- Code geared toward limiting size of register file on NVIDIA hardware
- Unsupported functions
Portable HIP Build System

1. Portable Makefiles
2. Portable Cmake
3. Library Equivalents
4. Specifying HIP Target
5. Identifying Compiler
6. Compiling for Host or Device
7. Compiler Defines
Exploiting the Power of HIP: Portable Build Systems

• One of the attractive features of HIP is that it can run on both AMD and Nvidia GPUs
• The HIP language has been developed with this in mind
  • Select ROCm and it will run on AMD GPUs
  • Select CUDA and it will run on Nvidia GPUs
• But it can be difficult to support this without a portable build system that switches between these two

• We’ll demonstrate two of the most common build systems that can support portable builds
  • make
  • cmake

• There have been changes with each ROCm version which may require some adjustments
**Portable Build Systems -- Makefile**

```
EXECUTABLE = ./vectoradd
all: $(EXECUTABLE) test
.PHONY: test

OBJECTS = vectoradd.o

CXXFLAGS = -g -O2 -DNDEBUG -fPIC
HIPCC_FLAGS = -O2 -g -DNDEBUG

HIP_PLATFORM ?= amd
HIP_PATH ?= $(shell hipconfig --path)
ifeq ($(HIP_PLATFORM), nvidia)
    HIPCC_FLAGS += -x cu -I$(HIP_PATH)/include /
    LDFLAGS = -lcudadevrt -lcudart_static -lrt -lpthread -ldl
endif
ifeq ($(HIP_PLATFORM), amd)
    HIPCC_FLAGS += -x hip -munsafe-fp-atomics
    LDFLAGS = -L${ROCM_PATH}/hip/lib -lamdhip64
endif

%.o: %.hip
    hipcc $(HIPCC_FLAGS) -c $^ -o $@
$(EXECUTABLE): $(OBJECTS)
    hipcc $< $(LDFLAGS) -o $@
test: $(EXECUTABLE)
    $(EXECUTABLE)
clean:
    rm -f $(EXECUTABLE) $(OBJECTS) build
```

*Pattern rule for HIP source*

*Setting default device compiler*

*Setting compile flags for different GPUs*
Using a portable Makefile

- For ROCm
  ```
  module load rocm
  module load cmake
  export CXX=${ROCM_PATH}/llvm/bin/clang++
  ```

- To build and run
  ```
  make vectoradd
  ./srun
  ```

- For CUDA
  ```
  module load rocm
  module load cuda
  module load cmake
  ```

- To build and run
  ```
  HIP_PLATFORM=nvidia make vectoradd
  ./srun
  ```

We still need HIP for the portability layer

Overriding default to compile with Nvidia
For Frontier

- For AMD programming environment
  module load PrgEnv-amd
  module load amd
  module load cmake
  export CXX=${ROCM_PATH}/llvm/bin/clang++

- To build and run
  make vectoradd
  srun ./vectoradd

- For Cray programming environment
  • module load PrgEnv-cray
  • module load amd-mixed
  • module load cmake

- To build and run
  • CXX=CC CRAY_CPU_TARGET=x86-64 make vectoradd
  • srun ./vectoradd
For Perlmutter

- For Perlmutter
  module load PrgEnv-gnu/8.3.3
  Module load hip/5.4.3
  module load PrgEnv-nvidia/8.3.3
  module load cmake

- To build and run
  HIP_PLATFORM=nvidia make vectoradd
  srun ./vectoradd

We still need HIP for the portability layer

Overriding default to compile with Nvidia
Portable Build Systems – CMakeLists.txt

```cmake
cmake_minimum_required(VERSION 3.21 FATAL_ERROR)
project(Vectoradd LANGUAGES CXX)

set (CMAKE_CXX_STANDARD 14)
if (NOT CMAKE_BUILD_TYPE)
  set(CMAKE_BUILD_TYPE RelWithDebInfo)
endif(NOT CMAKE_BUILD_TYPE)

string(REPLACE -O2 -O3 CMAKE_CXX_FLAGS_RELWITHDEBINFO ${CMAKE_CXX_FLAGS_RELWITHDEBINFO})

if (NOT CMAKE_GPU_RUNTIME)
  set(GPU_RUNTIME "ROCM" CACHE STRING "Switches between ROCM and CUDA")
else (NOT CMAKE_GPU_RUNTIME)
  set(GPU_RUNTIME "${CMAKE_GPU_RUNTIME}" CACHE STRING "Switches between ROCM and CUDA")
endif (NOT CMAKE_GPU_RUNTIME)
# Really should only be ROCM or CUDA, but allowing HIP because it is the currently built-in option
set(GPU_RUNTIMES "ROCM" "CUDA" "HIP")
if(NOT "${GPU_RUNTIME}" IN_LIST GPU_RUNTIMES)
  set(ERROR_MESSAGE "GPU_RUNTIME is set to "$\{GPU_RUNTIME\}". GPU_RUNTIME must be either HIP, ROCM, or CUDA.")
  message(FATAL_ERROR "$\{ERROR_MESSAGE\}"
endif()
# GPU_RUNTIME for AMD GPUs should really be ROCM, if selecting AMD GPUs
# so manually resetting to HIP if ROCM is selected
if ($\{GPU_RUNTIME\} MATCHES "ROCM")
  set(GPU_RUNTIME "HIP")
endif ($\{GPU_RUNTIME\} MATCHES "ROCM")
set_property(CACHE GPU_RUNTIME PROPERTY STRINGS $\{GPU_RUNTIMES\})
```

Setting GPU_RUNTIME

Defining GPU_RUNTIME will select ROCM or CUDA (e.g. -DGPU_RUNTIME=ROCM)
enable_language(${GPU_RUNTIME})
set(CMAKE_${GPU_RUNTIME}_EXTENSIONS OFF)
set(CMAKE_${GPU_RUNTIME}_STANDARD_REQUIRED ON)

set(VECTORADD_CXX_SRCS "")
set(VECTORADD_HIP_SRCS vectoradd.hip)

add_executable(vectoradd ${VECTORADD_CXX_SRCS} ${VECTORADD_HIP_SRCS})

set(ROCMCC_FLAGS "${ROCMCC_FLAGS} -munsafe-fp-atomics")
set(CUDACC_FLAGS "${CUDACC_FLAGS} ")

if (${GPU_RUNTIME} MATCHES "HIP")
  set(HIPCC_FLAGS "${ROCMCC_FLAGS}"")
else-if (${GPU_RUNTIME} MATCHES "CUDA")
  set(HIPCC_FLAGS "${CUDACC_FLAGS}"")
else (throw and error)
endif

set_source_files_properties(${VECTORADD_HIP_SRCS} PROPERTIES LANGUAGE ${GPU_RUNTIME})
set_source_files_properties(vectoradd.hip PROPERTIES COMPILE_FLAGS ${HIPCC_FLAGS})

install(TARGETS vectoradd)
Using a portable CMakeLists.txt

- For ROCm
  module load rocm
  module load cmake
  export CXX=${ROCM_PATH}/llvm/bin/clang++

- To Build
  mkdir build && cd build
  cmake..
  make VERBOSE=1
  ./vectoradd

- For CUDA
  module load rocm
cuda
  module load cmake

- To Build
  mkdir build && cd build
cmake -DCMAKE_GPU_RUNTIME=CUDA..
  make VERBOSE=1
  ./vectoradd

Overrides default GPU runtime to specify CUDA
Frontier and Perlmutter

- For Frontier
  ```
  module load rocm
  module load cmake
  export CXX=${ROCM_PATH}/llvm/bin/clang++
  ```
- To build and run
  ```
  mkdir build && cd build
  cmake ..
  make VERBOSE=1
  ./vectoradd
  ```
- For Perlmutter
  ```
  module load PrgEnv-gnu/8.3.3
  module load hip/5.4.3
  module load PrgEnv-nvidia/8.3.3
  module load cmake
  ```
- To build and run
  ```
  mkdir build && cd build
  cmake -DCMAKE_GPU_RUNTIME=CUDA ..
  make VERbose=1
  ./vectoradd
  ```
HIP build tools

- **hipconfig**
  - hip-clang-cxxflags : -isystem "/opt/rocm-5.6.0/include" -O3
  - hip-clang-ldflags : -O3 --hip-link --rtlib=compiler-rt -unwindlib=libgcc

- We can use the output from this command to set compiler options in the regular makefile system
  - --hip-link is only for clang++, so we use the more portable -L${ROCM_PATH}/hip/lib -lamdhip64 that will work with other compilers
  - clang++ -x hip is roughly equivalent to using hipcc

We can also get these variables and use them directly in a Makefile
- CXXFLAGS += $(shell $(HIP_PATH)/bin/hipconfig --cxx_config)
- CPPFLAGS += $(shell $(HIP_PATH)/bin/hipconfig --cpp_config)

- For both make and cmake, the .cu extension can be used as a quick workaround to renaming to .hip
Important CMake variables

- **CMAKE_HIP_ARCHITECTURES**
  - CMAKE_HIP_ARCHITECTURES="gfx90a;gfx908"
  - GPU_TARGETS="gfx90a;gfx908"
- **CMAKE_CXX_COMPILER:PATH=/opt/rocm/bin/amdclang++**
- **CMAKE_HIP_COMPILER_ROCM_ROOT:PATH=/opt/rocm-5.6.0** – to help cmake find the cmake config files
- **CMAKE_PREFIX_PATH=/opt/rocm-5.6.0**

Specifying HIP language – two possible ways
- project(MyProj LANGUAGES HIP)
- set_source_files_properties(MyLib.cu PROPERTIES LANGUAGE HIP)
- ???: Enable_language(HIP) Available in Cmake 3.21 and newer

Finding HIP packages and use results
- find_package(rocprim)
- target_link_libraries(MyLib PUBLIC roc::rocprim)

Using host and device from find_package(hip)
- target_link_libraries(MyLib PRIVATE hip::device)
- target_link_libraries(MyApp PRIVATE hip::host)
## Library Equivalents

<table>
<thead>
<tr>
<th>CUDA Library</th>
<th>ROCm Library</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>cuBLAS</td>
<td>rocBLAS</td>
<td>Basic Linear Algebra Subroutines</td>
</tr>
<tr>
<td>cuFFT</td>
<td>rocFFT</td>
<td>Fast Fourier Transfer Library</td>
</tr>
<tr>
<td>cuSPARSE</td>
<td>rocSPARSE</td>
<td>Sparse BLAS + SPMV</td>
</tr>
<tr>
<td>cuSolver</td>
<td>rocSOLVER</td>
<td>Lapack library</td>
</tr>
<tr>
<td>AMG-X</td>
<td>rocALUTION</td>
<td>Sparse iterative solvers and preconditioners with Geometric and Algebraic MultiGrid</td>
</tr>
<tr>
<td>Thrust</td>
<td>rocThrust</td>
<td>C++ parallel algorithms library</td>
</tr>
<tr>
<td>CUB</td>
<td>rocPRIM</td>
<td>Low Level Optimized Parallel Primitives</td>
</tr>
<tr>
<td>cuDNN</td>
<td>MIOpen</td>
<td>Deep learning Solver Library</td>
</tr>
<tr>
<td>cuRAND</td>
<td>rocRAND</td>
<td>Random Number Generator Library</td>
</tr>
<tr>
<td>EIGEN</td>
<td>EIGEN – HIP port</td>
<td>C++ template library for linear algebra: matrices, vectors, numerical solvers,</td>
</tr>
<tr>
<td>NCCL</td>
<td>RCCL</td>
<td>Communications Primitives Library based on the MPI equivalents</td>
</tr>
</tbody>
</table>
## ROCm CMake Packages

<table>
<thead>
<tr>
<th>Component</th>
<th>Package</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIP</td>
<td>hip</td>
<td>hip::host, hip::device</td>
</tr>
<tr>
<td>rocPRIM</td>
<td>rocprim</td>
<td>roc::rocprim</td>
</tr>
<tr>
<td>rocThrust</td>
<td>rocthrust</td>
<td>roc::rocthrust</td>
</tr>
<tr>
<td>hipCUB</td>
<td>hipcub</td>
<td>hip::hipcub</td>
</tr>
<tr>
<td>rocRAND</td>
<td>rocrand</td>
<td>roc::rocrand</td>
</tr>
<tr>
<td>rocBLAS</td>
<td>rocblas</td>
<td>roc::rocblas</td>
</tr>
<tr>
<td>rocSOLVER</td>
<td>rocsolver</td>
<td>roc::rocsolver</td>
</tr>
<tr>
<td>hipBLAS</td>
<td>hipblas</td>
<td>roc::hipblas</td>
</tr>
<tr>
<td>rocFFT</td>
<td>rocfft</td>
<td>roc::rocfft</td>
</tr>
<tr>
<td>hipFFT</td>
<td>hipfft</td>
<td>hip::hipfft</td>
</tr>
<tr>
<td>rocSPARSE</td>
<td>rocsparse</td>
<td>roc::rocsparse</td>
</tr>
<tr>
<td>hipSPARSE</td>
<td>hipsparse</td>
<td>roc::hipsparse</td>
</tr>
<tr>
<td>rocALUTION</td>
<td>rocalution</td>
<td>roc::rocalution</td>
</tr>
<tr>
<td>RCCL</td>
<td>rccl</td>
<td>rccl</td>
</tr>
<tr>
<td>MIOpen</td>
<td>miopen</td>
<td>MIOpen</td>
</tr>
<tr>
<td>MIGraphX</td>
<td>migraphx</td>
<td>migraphx::migraphx, migraphx::migraphx_c, migraphx::migraphx_cpu, migraphx::migraphx_gpu, migraphx::migraphx_onnx, migraphx::migraphx_tf</td>
</tr>
</tbody>
</table>
Identifying HIP Target Platform

• All HIP projects target either AMD or NVIDIA platform. The platform affects which headers are included and which libraries are used for linking.

• HIP_PLATFORM_AMD is defined if the HIP platform targets AMD. Note, HIP_PLATFORM_HCC was previously defined if the HIP platform targeted AMD, it is deprecated.

• HIP_PLATFORM_NVIDIA is defined if the HIP platform targets NVIDIA. Note, HIP_PLATFORM_NVCC was previously defined if the HIP platform targeted NVIDIA, it is deprecated.
Identifying the Compiler: hip-clang or nvcc

- Often, it's useful to know whether the underlying compiler is HIP-Clang or nvcc. This knowledge can guard platform-specific code or aid in platform-specific performance tuning.

```c
#ifdef __HIP_PLATFORM_AMD__
// Compiled with HIP-Clang
#endif

#ifdef __HIP_PLATFORM_NVIDIA__
// Compiled with nvcc
// Could be compiling either CUDA file or a host compile
#endif

#ifdef __CUDACC__
// Compiled with nvcc (CUDA language extensions enabled)
Compiler directly generates the host code (using the Clang x86 target) and passes the code to another host compiler. Thus, they have no equivalent of the __CUDA_ACC define.
```
Identifying Current Compilation Pass: Host or Device

• nvcc makes two passes over the code: one for host code and one for device code. HIP-Clang will have multiple passes over the code: one for the host code, and one for each architecture on the device code. __HIP_DEVICE_COMPILE__ is set to a nonzero value when the compiler (HIP-Clang or nvcc) is compiling code for a device inside a __global__ kernel or for a device function. __HIP_DEVICE_COMPILE__ can replace #ifdef checks on the __CUDA_ARCH__ define.

// #ifdef __CUDA_ARCH__
#if __HIP_DEVICE_COMPILE__

• Unlike __CUDA_ARCH__, the __HIP_DEVICE_COMPILE__ value is 1 or undefined, and it doesn't represent the feature capability of the target device.
## Compiler Defines

<table>
<thead>
<tr>
<th>Define</th>
<th>HIP-Clang</th>
<th>nvcc</th>
<th>Other (GCC, ICC, Clang, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HIP_PLATFORM_AMD</strong></td>
<td>Defined</td>
<td>Undefined</td>
<td>Defined if targeting AMD platform; undefined otherwise</td>
</tr>
<tr>
<td><strong>HIP_PLATFORM_NVIDIA</strong></td>
<td>Undefined</td>
<td>Defined</td>
<td>Defined if targeting NVIDIA platform; undefined otherwise</td>
</tr>
<tr>
<td><strong>HIP_DEVICE_COMPILE</strong></td>
<td>1 if compiling for device; undefined if compiling for host</td>
<td>1 if compiling for device; undefined if compiling for host</td>
<td>Undefined</td>
</tr>
<tr>
<td><strong>HIPCC</strong></td>
<td>Defined</td>
<td>Defined</td>
<td>Undefined</td>
</tr>
<tr>
<td>_<em>HIP_ARCH</em>*</td>
<td>0 or 1 depending on feature support (see rocm docs)</td>
<td>0 or 1 depending on feature support (see rocm docs)</td>
<td>0</td>
</tr>
</tbody>
</table>

### nvcc-related defines:

<table>
<thead>
<tr>
<th>Define</th>
<th>HIP-Clang</th>
<th>nvcc</th>
<th>Other (GCC, ICC, Clang, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CUDACC</strong></td>
<td>Defined</td>
<td>Undefined</td>
<td>Undefined if source code is compiled by nvcc; undefined otherwise</td>
</tr>
<tr>
<td><strong>NVCC</strong></td>
<td>Undefined</td>
<td>Defined</td>
<td>Undefined representing compute capability (e.g., &quot;130&quot;) if in device code; 0 if in host code</td>
</tr>
<tr>
<td><strong>CUDA_ARCH</strong></td>
<td>Undefined</td>
<td>Defined</td>
<td>Undefined</td>
</tr>
</tbody>
</table>

### hip-clang-related defines:

<table>
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<th>Other (GCC, ICC, Clang, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HIP</strong></td>
<td>Defined</td>
<td>Undefined</td>
<td>Undefined</td>
</tr>
</tbody>
</table>

### HIP-Clang common defines:

<table>
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<th>Define</th>
<th>HIP-Clang</th>
<th>nvcc</th>
<th>Other (GCC, ICC, Clang, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>clang</strong></td>
<td>Defined</td>
<td>Defined</td>
<td>Undefined</td>
</tr>
</tbody>
</table>
Other porting paths
Fortran

• First Scenario: Fortran + CUDA C/C++
  o Assuming there is no CUDA code in the Fortran files.
  o Hipify CUDA
  o Compile and link with hipcc
• Second Scenario: CUDA Fortran
  o There is no hipify equivalent but there is another approach…
  o HIP functions are callable from C, using `extern C`
CUDA Fortran -> Fortran + HIP C/C++

- There is no HIP equivalent to CUDA Fortran
- But HIP functions are callable from C, using `extern C`, so they can be called directly from Fortran
- The strategy here is:
  - **Manually port** CUDA Fortran code to HIP kernels in C-like syntax
  - Wrap the kernel launch in a C function
  - Call the C function from Fortran through Fortran’s ISO_C_binding. It requires Fortran 2008 because of the pointers utilization.
- This strategy should be usable by Fortran users since it is standard conforming Fortran
- ROCm has an interface layer, hipFort, which provides the wrapped bindings for use in Fortran
  - [https://github.com/ROCmSoftwarePlatform/hipfort](https://github.com/ROCmSoftwarePlatform/hipfort)
Alternatives to HIP

- Can also target AMD GPUs through OpenMP® 5.0 target offload
  - ROCm provides OpenMP® support
  - AMD OpenMP® compiler (AOMP) could integrate updated improvements regarding OpenMP® offloading performance, sometimes experimental stuff to validate before ROCm integration (https://github.com/ROCm-Developer-Tools/aomp)
- GCC provides OpenMP® offload support.
- GCC will provide OpenACC
- Clacc from ORNL: https://github.com/llvm-doe-org/llvm-project/tree/clacc/main OpenACC from LLVM™ only for C (Fortran and C++ in the future)
  - Translate OpenACC to OpenMP® Offloading
OpenMP® Offload GPU Support

- ROCm and AOMP
  - ROCm supports both HIP and OpenMP®
  - AOMP: the AMD OpenMP® research compiler, it is used to prototype the new OpenMP® features for ROCm

- HPE Compilers
  - Provides offloading support to AMD GPUs, through OpenMP, HIP, and OpenACC (only for Fortran)

- GNU compilers:
  - Provide OpenMP® and OpenACC offloading support for AMD GPUs
  - GCC 11: Supports AMD GCN gfx908
  - GCC 13: Supports AMD GCN gfx90a
Understanding the hardware options

- **rocminfo**
  - 110 CUs
  - Wavefront of size 64
  - 4 SIMDs per CU

#pragma omp target teams distribute parallel for simd

Options for pragma omp teams target:

- num_teams(220): Multiple number of workgroups with regards the compute units
- thread_limit(256): Threads per workgroup

- Thread limit is multiple of 64
- Teams*thread_limit should be multiple or a divisor of the trip count of a loop
Hipify example
Pennant mini-app
What about a real example of converting a CUDA code to HIP

Pennant is a mini-app for unstructured Lagrangian hydrodynamics

Download the Pennant implementation for CUDA

- tar -xzvf pennant-singlenode-cude.tgz
- cd PENNANT

Use the hipify command for converting a whole directory tree

- ./hipconvertinplace-perl.sh .
- mv src/HydroGPU.cu src/HydroGPU.hip

Additional source modifications

- most are related to the double2 type (HIP_vector_type <double,2)
- HIP has support for operations on the HIP_vector_type

Changes to the Makefile

- All compiles use the hipcc compiler (not split between device and host)
Additional source modifications

- Change all occurrences of __CUDACC__ to __HIPCC__ in src/Vec2.hh (double2 definition)
- Comment out all HIP_vector_type operations with an #ifdef __CUDACC__ in src/Vec2.hh
- Comment out atomicMin operation with #ifdef __CUDACC__ in src/HydroGPU.hip
- Move #include <hip/hip_runtime.h> (2 occurrences) in src/HydroGPU.hip into a #ifdef __HIPCC__ block in src/Vec2.hh
Changes to Vec2.hh – double2 type and hip include file
Additional changes to HydroGPU.hip
Makefile changes

- Change all CUDAC occurrences to CXX
- Comment out first CXX definition block so second one takes effect
  - Comment out the CXXFLAGS := $(CXXFLAGS_OPT) $(CPPFLAGS) line so next line takes effect
- Change nvcc to hipcc
- Change CXXFLAGS to add -std=c++14 --offload-arch=gfx90a
- Change LDFLAGS to -offload-arch=gfx90a instead of CUDA libraries
- Comment out all build rules for .cu files

- We'll do a more thorough code conversion in the exercises with a portable build system.
Makefile diffs

HIP Lecture Series

August 28th, 2023

[Public]
AMD GPU programming resources

- ROCm platform: https://github.com/RadeonOpenCompute/ROCm/
  - With instructions for installing from Debian/CentOS/RHEL binary repositories
  - Has links to source repositories for all components, including HIP
- HIP porting guide: https://github.com/ROCm-Developer-Tools/hip/blob/master/docs/markdown/hip_porting_guide.md
- ROCm/HIP libraries: https://github.com/ROCmSoftwarePlatform
- ROC-profiler: https://github.com/ROCm-Developer-Tools/rocprofiler
  - Collects application traces and performance counters
  - Trace timeline can be visualized with https://ui.perfetto.dev/
- AMD GPU ISA docs and more: https://developer.amd.com/resources/developer-guides-manuals/
Summary

- HIP has an extensive API similar to CUDA to enable portability
- Most of the changes are automatic
- The more specialized use of vector types on the GPU required some manual work
- Watch out for #ifdefs. They usually haven’t considered all the cases.
- The makefile required more changes than the source
- This is a simple makefile. More complex build systems may require more work.
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