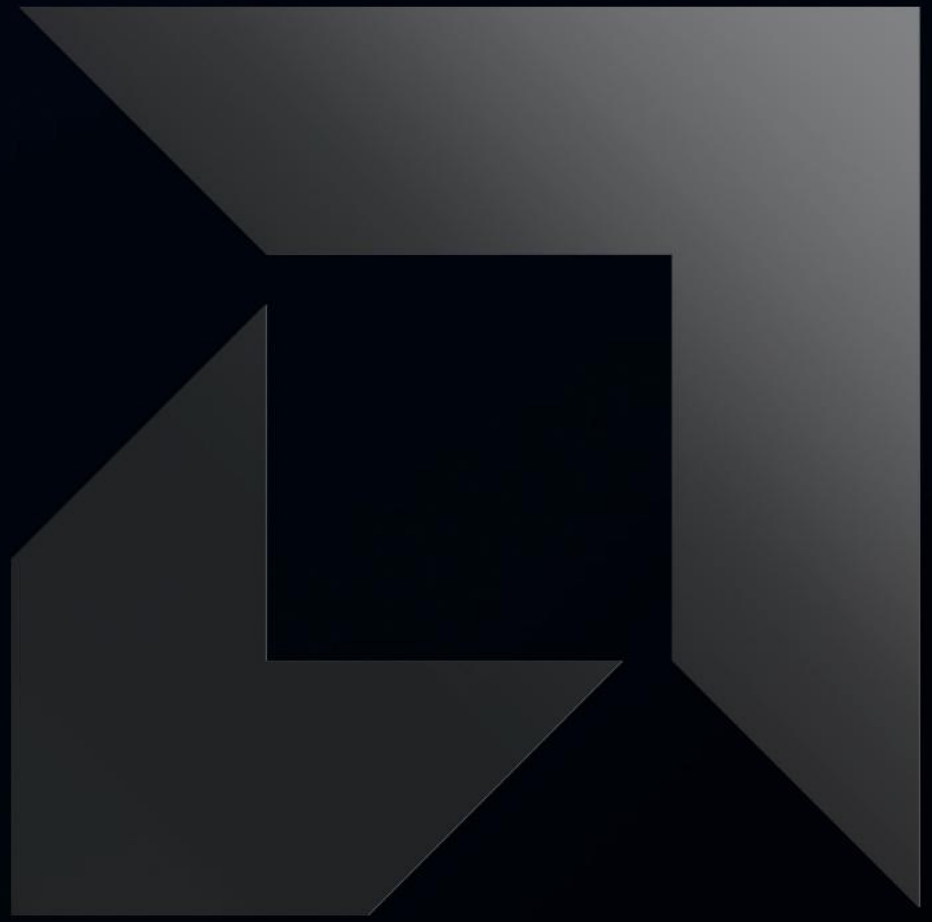


Porting code to HIP

Presenter: Bob Robey
AMD @ Tsukuba University
Oct 21-23, 2025

AMD
together we advance_

No one size fits all approach

Self contained GPU code

- Automatic conversion tools (hipify)
- Header file interception layer (hipiFLY)
  - Fast way to get running code
  - May break on creative use of previous device code

More complex accelerator layers

- Need combination of automatic conversion and manual rewrite
  - Abstraction layer needs to be adapted to use HIP API
  - Can later use HIP to target both ROCm and CUDA
  - Longer time to running 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

Hipify-clang

- More robust translation of the code
- Generates warnings and assistance for additional analysis
- High quality translation, particularly for cases where the user is familiar with the make system

Hipify-perl

It is located in `/opt/rocm/bin`

- Command line tool: `hipify-perl foo.cu > new_foo.cpp`

- Compile: `hipcc new_foo.cpp`

How does this 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

It is located in `/opt/rocm/bin`

Build from source (needs clang compiler)

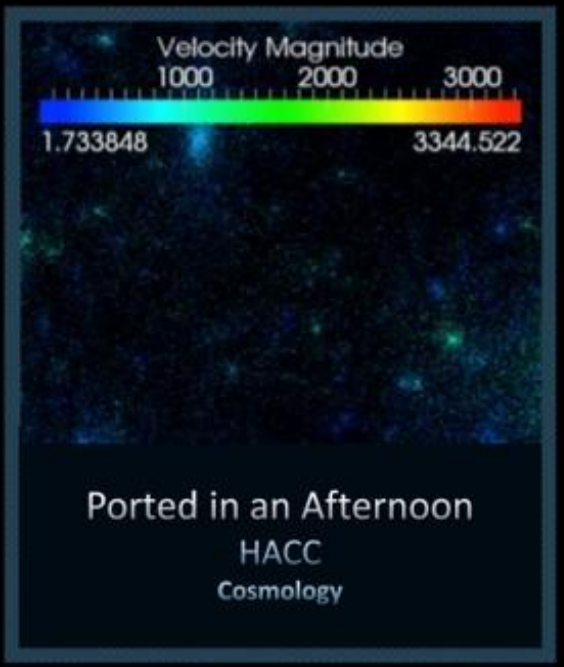
- hipify-clang has unit tests using LLVM™ lit/FileCheck (44 tests)

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`

`More info at: https://github.com/ROCm/HIPIFY/blob/master/README.md`

Can be used to perform build-time conversion if project can be automatically converted



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

NAMD Scalable Molecular Dynamics · LAMMPS · kokkos · Nekbone · GROMACS FAST. FLEXIBLE. FREE. · MILC · Chroma · TensorFlow

PYTORCH · GridTools · ALTAIR · SIRIUS · AMBER · PIConGPU · CP2K · LSMS

Other Hipify tools

Individual file tools (already discussed)

- hipify-perl
- hipify-clang

Recursive directory tools (also in `/opt/rocm/bin`)

- 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.

For example:
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).

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 (grep for "32" *just in case*). Use `#define WARPSIZE size`.
- 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 or CUDA intrinsics
  - Can either use inline GCN ISA, or convert it to HIP
- 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.

Notes

- Hipify-perl and hipify-clang can both convert library calls (i.e. cuBLAS becomes hipBLAS)
- CMake starting with version 3.21 can be used to automatically set up basic compilation flags by using enable_language(HIP), supports CMAKE_HIP_ARCHITECTURES for setting devices to build for

HIPIFLY: Intercept API method to choose GPU backend

- Enable running existing code on different backends with single header
- Can change between targeting CUDA and ROCm in one place
- Only works if no difference between API calls
- Existing code cannot use any CUDA specific hard coded values
- Performance needs to be evaluated on a case-by-case basis

```
#ifndef CUDA_TO_HIP_H
#define CUDA_TO_HIP_H

#include <hip/hip_runtime.h>

#define WARPSIZE 64
static constexpr int maxWarpsPerBlock = 1024/WARPSIZE;

#define CUFFT_D2Z HIPFFT_D2Z
#define CUFFT_FORWARD HIPFFT_FORWARD
#define CUFFT_INVERSE HIPFFT_BACKWARD
#define CUFFT_Z2D HIPFFT_Z2D
#define CUFFT_Z2Z HIPFFT_Z2Z

#define cudaDeviceSynchronize hipDeviceSynchronize
#define cudaError hipError_t
#define cudaError_t hipError_t
#define cudaErrorInsufficientDriver hipErrorInsufficientDriver
#define cudaErrorNoDevice hipErrorNoDevice
#define cudaEvent_t hipEvent_t
#define cudaEventCreate hipEventCreate
#define cudaEventElapsedTime hipEventElapsedTime
#define cudaEventRecord hipEventRecord
#define cudaEventSynchronize hipEventSynchronize
#define cudaFree hipFree
#define cudaFreeHost hipHostFree
#define cudaGetDevice hipGetDevice
#define cudaGetDeviceCount hipGetDeviceCount
#define cudaGetErrorString hipGetErrorString
#define cudaGetLastError hipGetLastError
#define cudaHostAlloc hipHostMalloc
#define cudaHostAllocDefault hipHostMallocDefault
#define cudaMalloc hipMalloc
#define cudaMemcpy hipMemcpy
#define cudaMemcpyAsync hipMemcpyAsync
#define cudaMemcpyDeviceToHost hipMemcpyDeviceToHost
#define cudaMemcpyDeviceToDevice hipMemcpyDeviceToDevice
#define cudaMemcpyHostToDevice hipMemcpyHostToDevice
#define cudaMemGetInfo hipMemGetInfo
#define cudaMemset hipMemset
#define cudaReadModeElementType hipReadModeElementType
```

Link to the header file:
https://github.com/amd/HPCTrainingExamples/blob/main/hipifly/vector_add/src/cuda_to_hip.h

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 with 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

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

ifeq ($(HIP_PLATFORM), nvidia)
   HIP_PATH ?= $(shell hipconfig --path)
   HIPCC_FLAGS += -x cu -I${HIP_PATH}/include/
endif

ifeq ($(HIP_PLATFORM), amd)
   HIPCC_FLAGS += -x hip -munsafe-fp-atomics
endif
```

Setting default device compiler

Setting compile flags for different GPUs

```
%.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

Using a portable Makefile

- For ROCm

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

To build and run:

```
make vectoradd
./vectoradd
```

- For CUDA

```
module load rocm
module load cuda
```

We still need HIP for the portability layer

To build and run:

Overriding default to compile with nvidia

```
HIP_PLATFORM=nvidia make vectoradd
./vectoradd
```

Portable Build Systems – CMakeLists.txt (1 of 3)

```
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 (CMAKE_GPU_RUNTIME)
   set(GPU_RUNTIME "${CMAKE_GPU_RUNTIME}" CACHE STRING "Switches between ROCM and CUDA")
endif (NOT CMAKE_GPU_RUNTIME)
```

Setting GPU_RUNTIME

Portable Build Systems – CMakeLists.txt (2 of 3)

```
# Should only be ROCM or CUDA, but allowing HIP because it is the currently built-in option
# Select with e.g., -DGPU_RUNTIME=ROCM
set(GPU_RUNTIMES "ROCM" "CUDA" "HIP")
if(NOT "${GPU_RUNTIME}" IN_LIST GPU_RUNTIMES)
    set(ERROR_MESSAGE
        "GPU_RUNTIME is set to \"${GPU_RUNTIME}\".\nGPU_RUNTIME must be either HIP, ROCM, or CUDA.")
    message(FATAL_ERROR ${ERROR_MESSAGE})
endif()

# GPU_RUNTIME should really be ROCM for 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})

enable_language(${GPU_RUNTIME})
set(CMAKE_${GPU_RUNTIME}_EXTENSIONS OFF)
set(CMAKE_${GPU_RUNTIME}_STANDARD_REQUIRED ON)
```

Enabling either CUDA or HIP (ROCM)

Portable Build Systems – CMakeLists.txt (3 of 3)

```
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 (${GPU_RUNTIME} MATCHES "CUDA")
   set(HIPCC_FLAGS "${CUDACC_FLAGS}")
endif (${GPU_RUNTIME} MATCHES "HIP")

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)
```

Setting different flags for each GPU type

Setting language type for HIP source files

Setting device compile flags

Using a portable CMakeLists.txt

- For ROCm

```
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 CUDA

```
module load rocm
module load cuda
module load cmake
```

To build and run:

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

Important CMake variables

- CMAKE_HIP_ARCHITECTURES
  - `CMAKE_HIP_ARCHITECTURES="gfx90a;gfx908"`
  - `GPU_TARGETS="gfx90a;gfx908"`

  List of gfx models: https://llvm.org/docs/AMDGPUUsage.html

  Find the gfx model with rocminfo: `rocminfo | grep gfx | sed -e 's/Name://' | head -1 |sed 's/ //g'`

- `CMAKE_CXX_COMPILER:PATH=/opt/rocm/bin/amdclang++`
- `CMAKE_HIP_COMPILER_ROCM_ROOT:PATH=/opt/rocm` – to help cmake find the cmake config files
- `CMAKE_PREFIX_PATH=/opt/rocm`

- 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)`

CUDA Fortran ➡ Fortran + HIP C/C++

- There is no HIP equivalent to CUDA Fortran
- HIP functions are callable from C, using `extern C`, so they can be called directly from Fortran
- The strategy here is:
  1) **Manually port** CUDA Fortran code to HIP kernels in C-like syntax
  2) Wrap the kernel launch in a C function
  3) Call the C function from Fortran through Fortran's ISO_C_binding. It requires Fortran 2008 because of using pointers to share data.
- 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/ROCm/hipfort

Hands-on exercises

Located in our HPC Training Examples repo:

https://github.com/amd/HPCTrainingExamples

A table of contents for the READMEs if available at the top-level **README** in the repo

Relevant exercises for this presentation located in:

- HIPIFY directory
- hipifly directory
- HIPFort directory

Link to instructions on how to run the HIPIFY tests: **HIPIFY/README.md**

Log into the AAC node and clone the repo:

```
ssh <username>@aac6.amd.com –p 7000 -i <path_to_ssh_key>
git clone https://github.com/amd/HPCTrainingExamples.git
```

Disclaimer

The information presented in this document is for informational purposes only and may contain technical inaccuracies, omissions, and typographical errors. The information contained herein is subject to change and may be rendered inaccurate for many reasons, including but not limited to product and roadmap changes, component and motherboard version changes, new model and/or product releases, product differences between differing manufacturers, software changes, BIOS flashes, firmware upgrades, or the like. Any computer system has risks of security vulnerabilities that cannot be completely prevented or mitigated. AMD assumes no obligation to update or otherwise correct or revise this information. However, AMD reserves the right to revise this information and to make changes from time to time to the content hereof without obligation of AMD to notify any person of such revisions or changes.

THIS INFORMATION IS PROVIDED ‘AS IS.” AMD MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE CONTENTS HEREOF AND ASSUMES NO RESPONSIBILITY FOR ANY INACCURACIES, ERRORS, OR OMISSIONS THAT MAY APPEAR IN THIS INFORMATION. AMD SPECIFICALLY DISCLAIMS ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, OR FITNESS FOR ANY PARTICULAR PURPOSE. IN NO EVENT WILL AMD BE LIABLE TO ANY PERSON FOR ANY RELIANCE, DIRECT, INDIRECT, SPECIAL, OR OTHER CONSEQUENTIAL DAMAGES ARISING FROM THE USE OF ANY INFORMATION CONTAINED HEREIN, EVEN IF AMD IS EXPRESSLY ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Git and the Git logo are either registered trademarks or trademarks of Software Freedom Conservancy, Inc., corporate home of the Git Project, in the United States and/or other countries

LLVM is a trademark of LLVM Foundation

Perl is a trademark of Perl Foundation.


AMD