An Easier, Short Path to Productive Heterogeneous Programming

Source-to-Source

CUDA* to SYCL* Code Migration Tool

Intel® DPC++ Compatibility Tool | Coming Soon: Open Source SYCLomatic project

Wang Zhiming, Senior Software Engineer
May 2022
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Agenda

- Easier, Short Path to Productive Heterogeneous Programming
- What is Intel® DPC++ Compatibility Tool
- Open Source project: SYCLomatic (Coming Soon)
- SYCLomatic Usage Flow
- SYCLomatic Architecture
- Migrating VectorAdd Example
- Migration Rule Example
- User Defined Migration Rule
- Summary / Call to Action
Diverse architectures have made software development increasingly complex for developers.

SYCL* with oneAPI open, cross-architecture, standards-based programming

- Allows developers to expand the value of their investments across architectures
- Provides choice & freedom from proprietary, single-vendor lock-in

Intel embraces open development to advance ecosystem innovation

- CUDA* to SYCL code migration tool provides developers a productive path to create single-source portable code

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What is Intel® DPC++ Compatibility Tool

- The tool assists in migrating your existing CUDA* code to SYCL* code which can run on any platform that has SYCL compiler support.

- The tool ports both CUDA language kernels and library API calls.

- Tool was developed by analyzing declaratory code of CUDA and developing migration rules that allow porting of CUDA code to SYCL.

- The goal of the tool: make it as easy as possible for developers to migrate their existing CUDA codebase to SYCL.

- Intel® DPC++ Compatibility Tool is part of the Intel® oneAPI Base Toolkit.

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Open Source Project SYCLomatic – Coming Soon

Intel is providing a CUDA* to SYCL* migration tool under an open source license as project SYCLomatic.

- Source to source code migration tool that enables developers to create single-source, portable code for hardware targets regardless of vendor
- Simplifies development while delivering performance and productivity
- Reduces time and costs for code maintenance

A community to share, collaborate & contribute software technologies

Available on GitHub in the coming weeks

- [github.com/oneapi-src/SYCLomatic](https://github.com/oneapi-src/SYCLomatic)
- [github.com/oneapi-src/SYCLomatic-test](https://github.com/oneapi-src/SYCLomatic-test)

Use the tool, please provide feedback!
SYCLomatic Usage Workflow

- Collect compilation options of the Developer’s CUDA* source from project build scripts, eg. Makefile, vcxproj file

- *Assist* developers migrating code written in CUDA to SYCL by generating SYCL code wherever possible

- Typically, 90%-95%+ of CUDA code automatically migrates to SYCL code

- Inline comments are provided to help developer complete and tune the code

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* Intel estimates as of September 2021. Based on measurements on a set of 70 HPC benchmarks and samples, with examples like Rodinia, SHOC, PENNANT. Results may vary.

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**SYCLomatic Architecture** (2 of 2 slides)

### Helper User interface
- Memory API
- Device API
- Image API
- Atomics API
- Math API
- oneDPL Extensions
- BLAS Wrappers

### Helper Implementation
- Memory manager singleton
- Device manager singleton
- Image wrappers
- oneDPL extensions implementation

### Helper header library
- **Legend**
  - Helper header library component: A → B (A uses B)
  - SYCL/oneAPI component: No arrow

- **Map host virtual pointers and SYCL buffers**
- **b.** Manages all SYCL capable devices available on the system
- **c.** Address semantic differences
Migrating VectorAdd Example

CUDA® Code

```c
#include <cuda.h>
#include <stdio.h>
define VECTOR_SIZE 256

global void VectorAddKernel(float* A, float* B, float* C)
{
    A[threadIdx.x] = threadIdx.x + 1.0f;
    B[threadIdx.x] = threadIdx.x + 1.0f;
    C[threadIdx.x] = A[threadIdx.x] + B[threadIdx.x];
}

int main()
{
    float *d_A, *d_B, *d_C;
    cudaMalloc(&d_A, VECTOR_SIZE*sizeof(float));
    cudaMalloc(&d_B, VECTOR_SIZE*sizeof(float));
    cudaMalloc(&d_C, VECTOR_SIZE*sizeof(float));

    d_A = malloc_device<float>(VECTOR_SIZE, q_ct1);
    d_B = malloc_device<float>(VECTOR_SIZE, q_ct1);
    d_C = malloc_device<float>(VECTOR_SIZE, q_ct1);

    // More CUDA code
}
```

SYCL® Code

```c
#include <CL/sycl.hpp>
#include <dpct/dpct.hpp>
define VECTOR_SIZE 256

void VectorAddKernel(float* A, float* B, float* C, sycl::nd_item<3> *item_ct1)
{
    A[item_ct1.get_local_id(2)] = item_ct1.get_local_id(2) + 1.0f;
    B[item_ct1.get_local_id(2)] = item_ct1.get_local_id(2) + 1.0f;
    C[item_ct1.get_local_id(2)] =
        A[item_ct1.get_local_id(2)] + B[item_ct1.get_local_id(2)];
}

int main()
{
    dpct::device_ext &dev_ct1 = dpct::get_current_device();
    sycl::queue &q_ct1 = dev_ct1.default_queue();
    float *d_A, *d_B, *d_C;

    d_A = malloc_device<float>(VECTOR_SIZE, q_ct1);
    d_B = malloc_device<float>(VECTOR_SIZE, q_ct1);
    d_C = malloc_device<float>(VECTOR_SIZE, q_ct1);

    // More SYCL code
}
```

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Migrating VectorAdd Example (2)

**CUDA* Code**

```c
VectorAddKernel<<<1, VECTOR_SIZE>>>(d_A, d_B, d_C);

float Result[VECTOR_SIZE] = { };  #4
cudaMemcpy(Result, d_C, VECTOR_SIZE*sizeof(float), cudaMemcpyDeviceToHost);  #5

for (int i = 0; i < VECTOR_SIZE; i++) {
    if (i % 16 == 0) {
        printf("\n");
    }
    printf("%f ", Result[i]);  
}
return 0;
```

**SYCL* Code**

```c
q_ct1.submit([&](sycl::handler &cgh) {
    cgh.parallel_for(sycl::nd_range<3>(
        sycl::range<3>(1, 1, VECTOR_SIZE),
        sycl::range<3>(1, 1, VECTOR_SIZE)),
        [=](sycl::nd_item<3> item_ct1) {
            VectorAddKernel(d_A, d_B, d_C, item_ct1);
        });
});

float Result[VECTOR_SIZE] = { };  #4
q_ct1.memcpy(Result, d_C, VECTOR_SIZE * sizeof(float)).wait();  #5

for (int i = 0; i < VECTOR_SIZE; i++) {
    if (i % 16 == 0) {
        printf("\n");
    }
    printf("%f ", Result[i]);
}
return 0;
```

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Sample code
- Input code: `cudaMalloc(&d_A, vector_size * sizeof(float));`
- Output code: `d_A = sycl::malloc_device<float>(vector_size, dpct::get_default_queue());`

AST tree

AST Matcher
- `callExpr(allOf(callee(functionDecl(hasAnyName("cudaMalloc"))...).bind("callExpr"))`}

AST Matcher Action
- Visit the `callExpr` node, analyze the parameters of the `cudaMalloc`, and generate migration result
User Defined Migration Rule

- Provides a way to extend the migration capability by defining migration rule in Yaml file
- Example: Rule “rule_forceinline” is used to guide the migration of macro “__forceinline__”
  
  ```yaml
  Rule: rule_forceinline
  Kind: Macro
  Priority: Takeover
  In: __forceinline__
  Out: inline
  Includes: ["header1.h"]
  
  # [Required] The unique name of the rule
  # [Required] The kind of the rule [Macro |API]
  # [Required] The priority of the rule [Takeover |Default |Fallback]
  # [Required] The target macro name in the input source code
  # [Required] The migrated name of the macro in output source code
  # [Required] A list of header file name which the new macro depends on, can be an empty list
  
  User defined migration rule target to cover migration of API, Datatype, Class, ENUM type, Macro, Include, Specifier/Qualifier/Attribute
  - Part of feature will be available in next Intel oneAPI release
Summary / Call-to-Action

- Both Intel® DPC++ Compatibility Tool and SYCLomatic assist in migrating your existing CUDA* code to SYCL* code which can run on any platform that has SYCL compiler support.

- Intel® DPC++ Compatibility Tool is the Intel product version of SYCLomatic.

- SYCLomatic will open source in coming weeks.

- Try it
  - Intel® DPC++ Compatibility Tool in Intel® oneAPI Base Toolkit - Free: intel.com/oneAPI-BaseKit
  - github.com/oneapi-src/SYCLomatic coming soon

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More Resources

- **SYCLomatic Project** on GitHub: [GetStartedGuide.md](#), [Contributing.md](#) guide (coming soon)
- Get started developing
  - **Book**: Mastering Programming of Heterogeneous Systems using C++ & SYCL
  - **Essentials of SYCL training**
  - **The oneAPI samples** on Github
- **oneAPI specification** and **SYCL** specification
- **Intel® DevCloud** - A free environment to access Intel® oneAPI Tools and develop and test code across a variety of Intel® architectures (CPU, GPU, FPGA)
- CodeProject: [Using oneAPI to convert CUDA code to SYCL](#)