SYCLomatic compatibility library: Making Migration to SYCL Easier

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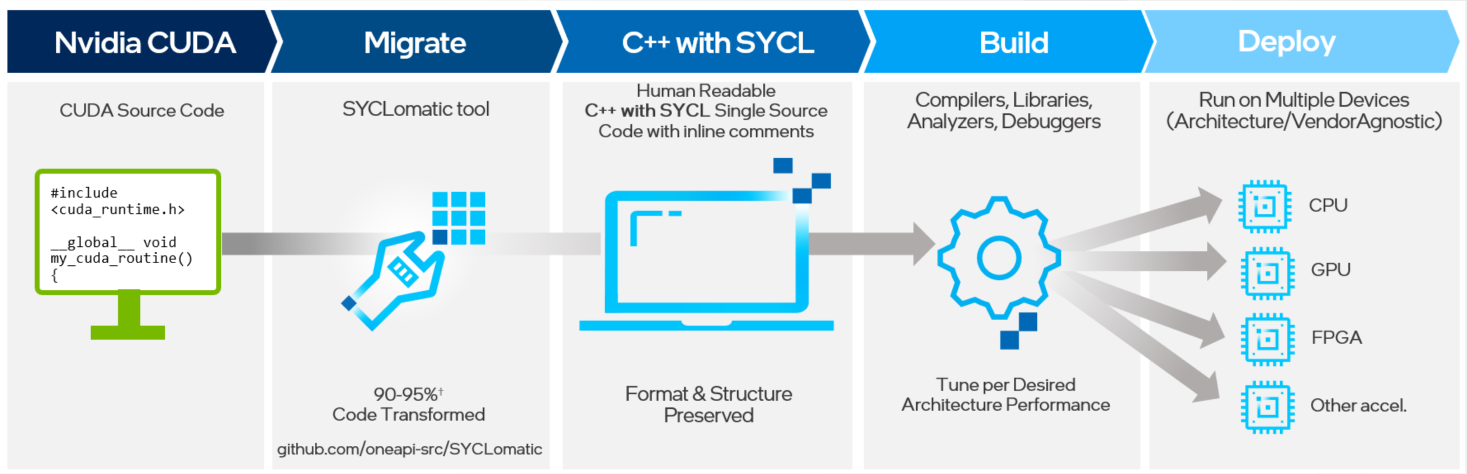
Notices & Disclaimers

Agenda

- The Background of SYCLomatic
- Design Philosophy
- Addressing Semantic Difference
  - Accessibility of sycl::queue
  - Pointer-like memory operations for targets, which don't support USM
  - Interface to fetch image
- Compatible APIs
  - Atomic operations
  - Utility function for memory allocation
  - Utility function for 2D/3D memory operation
  - Compatible APIs to popular CUDA libraries
- Summary / Call to Action

Background of SYCLomatic

- 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



Nvidia CUDA → **Migrate** → **C++ with SYCL** → **Build** → **Deploy**

CUDA Source Code

```
#include
<cuda_runtime.h>

__global__ void
my_cuda_routine()
{
```

SYCLomatic tool

90-95%+
Code Transformed

github.com/oneapi-src/SYCLomatic

Human Readable
C++ with SYCL Single Source
Code with inline comments

Format & Structure
Preserved

Compilers, Libraries,
Analyzers, Debuggers

Tune per Desired
Architecture Performance

Run on Multiple Devices
(Architecture/VendorAgnostic)

CPU

GPU

FPGA

Other accel.

+ 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.

*Other names and brands may be claimed as the property of others.

Design Philosophy

- Assisting the migration of SYCLomatic through addressing
  - Difference in language API design
  - Difference in runtime/library API design

- Friendly interface for developers
  - Can be used as a standalone library without SYCLomatic

- Performance Aspirations
  - To minimize the performance impact caused by the compatibility library APIs
  - To leverage the performance benefit of SYCL runtime and SYCL library

- Maintainability
  - Keeping backward compatibility
  - Targeting reusable class/API design

Addressing Semantic Difference – sycl::queue

Difference

- Missing context to record the device selection in the current thread
  - Programmer needs to select the device every time before getting a queue
- No default sycl::queue is available in sycl::device
  - Programmer needs to passing the created queue around the host functions
- No single API call to synchronize all queues on a device

Solution

- Singleton class dev_mgr
  - Keeping a map to record the thread’s tid and the selected device
- A class device_ext for each device
  - The “default queue”
  - Recording all the created queue in the device

Addressing Semantic Difference – sycl::queue (example)

```
__global__ void kernel_foo() {}

int foo() {
  kernel_foo<<<1,1,0>>>();
}

int foo2() {
  cudaSetDevice(1);
}
```

```
void kernel_foo() {}

int foo() {
  dpct::get_default_queue() parallel_for(
        sycl::nd_range<3>(sycl::range<3>(1, 1, 1),
        sycl::range<3>(1, 1, 1)),
          [=](sycl::nd_item<3> item_ct1) {
            kernel_foo();
          }
        );
}

int foo2() {
  dpct::select_device(1);
}
```

Addressing Semantic Difference –
Pointer-like memory operations for targets, which don’t support USM

Difference

- Pointer-like operations are used by CUDA programmers

```
int foo() {
  float *h_A = (float *)malloc(size);
  float *d_A = NULL;

  cudaMalloc((void **)&d_A, 100);
  cudaMemcpyAsync(d_A, h_A, size,
    cudaMemcpyHostToDevice);
}
```

Solution

- Singleton class mem_mgr
  - Creating a “virtual” pointer for each device memory allocation
  - Providing a function to retrieve the accessor from a “virtual pointer”

```
int foo() {
  float *h_A = (float *)malloc(size);
  float *d_A = NULL;

  d_A = (float *)dpct::dpct_malloc(100);
  dpct::async_dpct_memcpy(d_A, h_A, size,
    dpct::host_to_device);
}
```

Addressing Semantic Difference – Flexible interface to fetch Image data

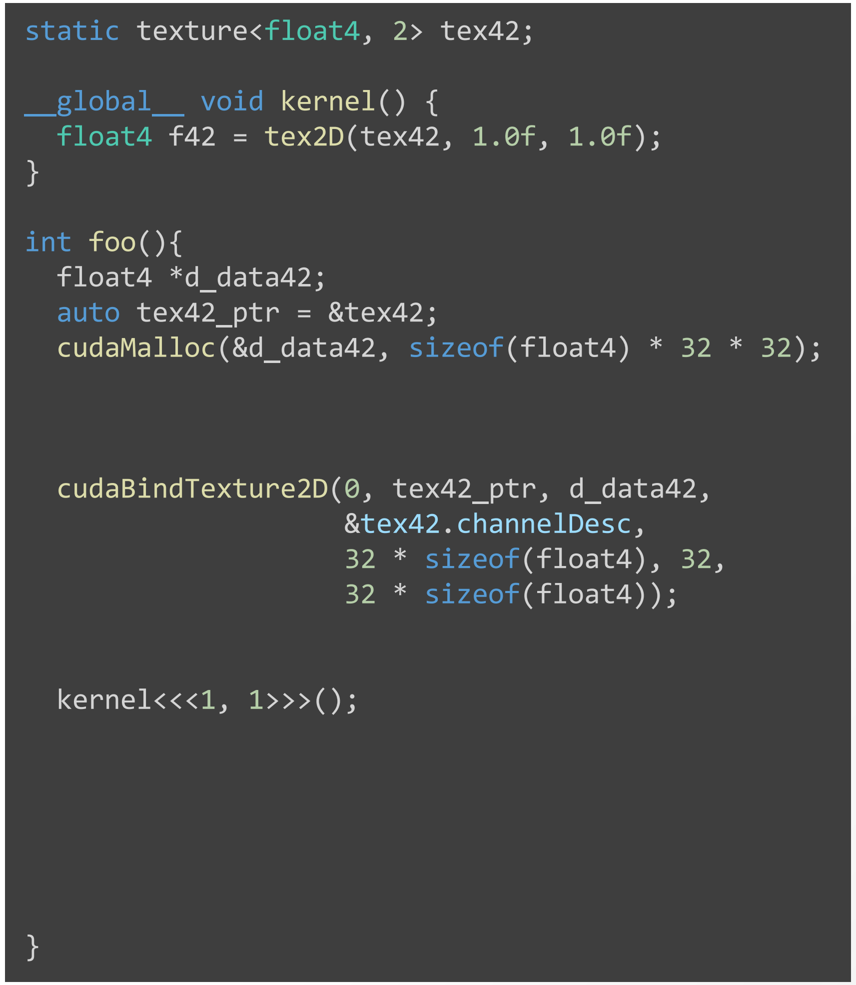
Difference

- CUDA workflow:
  - Allocating device memory
  - Creating texture
  - Binding a texture to the memory
- SYCL image workflow:
  - The memory is allocated when sycl::image is constructed
  - The format, dimension and pitch of the image cannot be changed

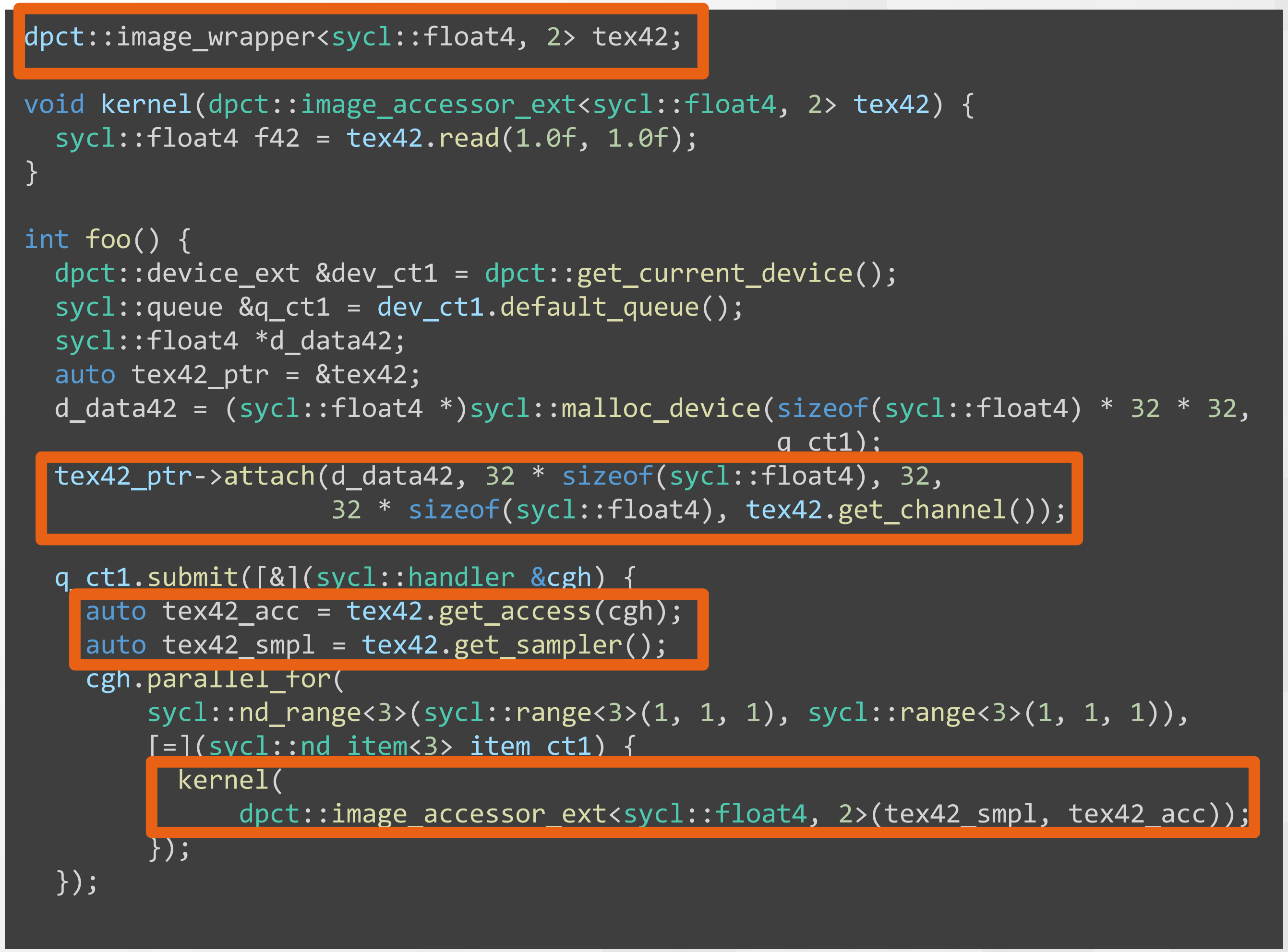
Solution

- When migrating cudaBindTexture()
  - Recording the device pointer, dimension and channel info into an image_wrapper
- Lazy constructing the sycl::image base on the info in the image_wrapper when needed

Addressing Semantic Difference – Flexible interface to fetch Image data (example)



```
static texture<float4, 2> tex42;

__global__ void kernel() {
  float4 f42 = tex2D(tex42, 1.0f, 1.0f);
}

int foo(){
  float4 *d_data42;
  auto tex42_ptr = &tex42;
  cudaMalloc(&d_data42, sizeof(float4) * 32 * 32);



  cudaBindTexture2D(0, tex42_ptr, d_data42,
                    &tex42.channelDesc,
                    32 * sizeof(float4), 32,
                    32 * sizeof(float4));


  kernel<<<1, 1>>>();






}
```



```
dpct::image_wrapper<sycl::float4, 2> tex42;

void kernel(dpct::image_accessor_ext<sycl::float4, 2> tex42) {
  sycl::float4 f42 = tex42.read(1.0f, 1.0f);
}

int foo() {
  dpct::device_ext &dev_ct1 = dpct::get_current_device();
  sycl::queue &q_ct1 = dev_ct1.default_queue();
  sycl::float4 *d_data42;
  auto tex42_ptr = &tex42;
  d_data42 = (sycl::float4 *)sycl::malloc_device(sizeof(sycl::float4) * 32 * 32,
                                                 q_ct1);
  tex42_ptr->attach(d_data42, 32 * sizeof(sycl::float4), 32,
                    32 * sizeof(sycl::float4), tex42.get_channel());

  q_ct1.submit([&](sycl::handler &cgh) {
    auto tex42_acc = tex42.get_access(cgh);
    auto tex42_smpl = tex42.get_sampler();
    cgh.parallel_for(
        sycl::nd_range<3>(sycl::range<3>(1, 1, 1), sycl::range<3>(1, 1, 1)),
        [=](sycl::nd_item<3> item_ct1) {
          kernel(
              dpct::image_accessor_ext<sycl::float4, 2>(tex42_smpl, tex42_acc));
        });
  });
```

Compatible APIs – Free functions for atomic operation

Difference

- In SYCL 2020, atomic operations require 2 steps:
  - Constructing an atomic_ref
  - Performing the required operation on the created atomic_ref

Solution

- Free functions to wrap the 2 steps in a single function call

```
__device__ void addByte(unsigned int *s_WarpHist,
                        unsigned int data) {
  atomicAdd(s_WarpHist + data, 1);
}
```

```
__device__ void addByte(unsigned int *s_WarpHist,
                        unsigned int data) {
  dpct::atomic_fetch_add<sycl::access::address_space::generic_space>(
    s_WarpHist + data, 1);
}
```

Compatible APIs –
Utility Classes to simplify device memory allocation

Difference

- SYCL does not provide features to declare static/global variable for device

Solution

- Class constant_memory to recording the dimension/default value
  - Allocate device memory only when needed
  - Create accessor only when needed

```
__constant__ int t1;
__constant__ float t2[4][5];

__global__ void kernel() {
  int a = t1;
}

int foo() {



  kernel<<<1, 1>>>();





}
```

```
static dpct::constant_memory<int, 0> t1;
static dpct::constant_memory<float, 2> t2(4, 5);

void kernel(int t1) {
  int a = t1;
}

int foo() {
  dpct::get_default_queue().submit([&](sycl::handler &cgh) {
    t1.init();
    auto t1_ptr_ct1 = t1.get_ptr();
    cgh.parallel_for(
        sycl::nd_range<3>(sycl::range<3>(1, 1, 1), sycl::range<3>(1, 1, 1)),
        [=](sycl::nd_item<3> item_ct1) {
          kernel(*t1_ptr_ct1);
        });
  });
}
```

Compatible APIs –
2D and 3D Memory Operations

Difference

- SYCL does not provide function to allocate/copy/set 2D or 3D memory
- Cannot copy to certain range like cudaMemcpy2DAsync()

Solution

- Adding free functions to
  - Handling pitch size during allocation
  - Recording pitch information
  - Provide copy to range feature

```
int foo() {


  int size = 10 * sizeof(float);
  int pitch_des = size, pitch_src = size;
  int width = size, height = size;
  float *h_A = (float *)malloc(size);
  float *d_A = NULL;

  cudaMalloc((void **)&d_A, size);
  cudaMemcpy2DAsync(d_A, pitch_des, h_A, pitch_src,
    width, height, cudaMemcpyHostToDevice, cudaStreamDefault);
}
```

```
int foo() {
  dpct::device_ext &dev_ct1 = dpct::get_current_device();
  sycl::queue &q_ct1 = dev_ct1.default_queue();

  int size = 10 * sizeof(float);
  int pitch_des = size, pitch_src = size;
  int width = size, height = size;
  float *h_A = (float *)malloc(size);
  float *d_A = NULL;

  d_A = (float *)sycl::malloc_device(size, q_ct1);
  dpct::async_dpct_memcpy(d_A, pitch_des, h_A, pitch_src, width, height,
                          dpct::host_to_device);
}
```

Compatible APIs –
Compatible APIs for popular CUDA libraries

Difference

- Libraries which provide similar feature may have quite different API design concept
- For example
  - curand(CUDA) workflow:
    curandGenerator_t can set generator type dynamically after been constructed
  - oneapi::mkl::rng(Intel® oneAPI) workflow:
    The type of generator cannot be changed after construction

Solution

- Adding utility class/functions for different cases
- In the case of curand,
  - Adding template class which take generator type as a pointer and the class is derived from a non-template base class
  - Using the base class to migrate curandGenerator_t
  - Creating new mkl generator and updating the pointer when changing the generator
- Current supported libraries:
  - BLAS, CCL, DNN, STL algorithm, FFT, Rand

Summary / Call-to-Action

- The compatibility library simplify the auto migration process of SYCLomatic

- The friendly API design can help developers to create SYCL-based projects with less effort

- Future work
  - Trying to promote some APIs to SYCL spec/extension
  - Improving coverage of popular libraries
  - Providing more detailed spec of the compatibility library

- Call for contribution: SYCLomatic & SYCLomatic test

More Resources

- SYCLomatic Project on GitHub: GetStartedGuide.md, Contributing.md guide
- 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® oneAPI Toolkits
- 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

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