DATA AND DEPENDENCIES

LEARNING OBJECTIVES

- Learn about how to create dependencies between kernel functions
- Learn about how to move data between the host and device(s)
- Learn how to represent basic data flow graphs

ACCESS/BUFFER AND USM

There are two ways to move data and create dependencies between kernel functions in SYCL

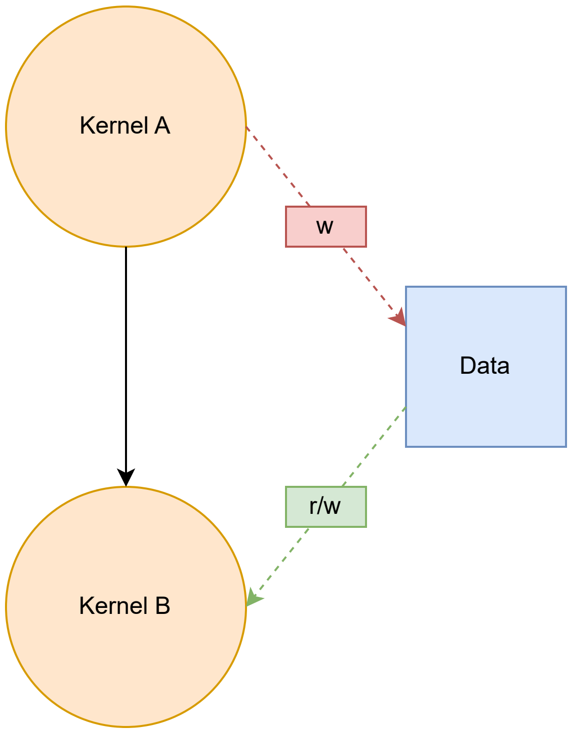
Buffer/accessor data movement model

- Data dependencies analysis
- Implicit data movement

USM data movement model

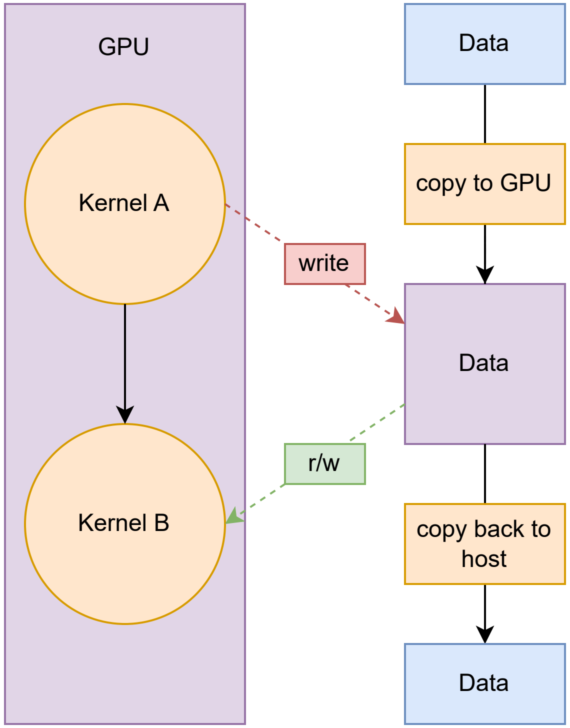
- Manual chaining of dependencies
- Explicit data movement

CREATING DEPENDENCIES



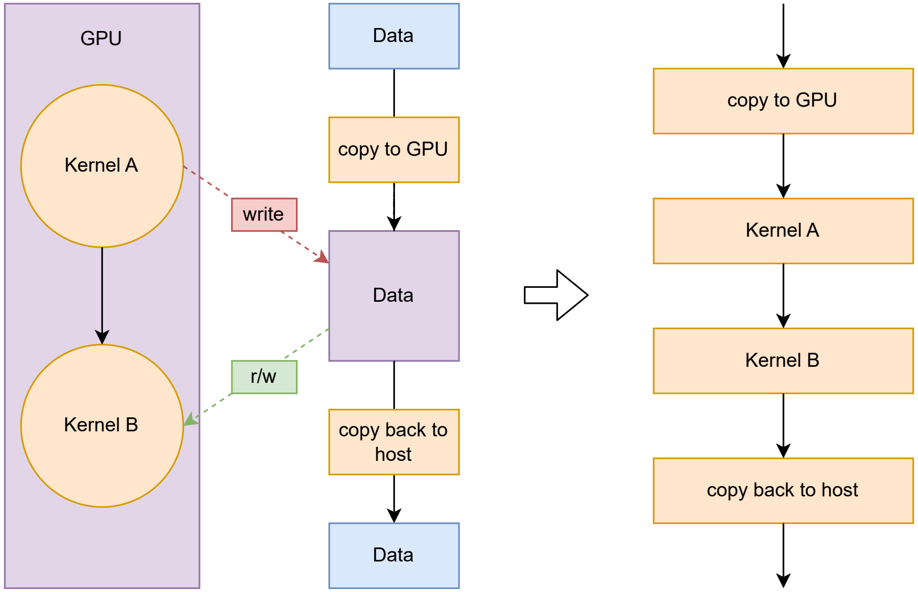
- Kernel A first writes to the data
- Kernel B then reads from and writes to the data
- This creates a read-after-write (RAW) relationship
- There must be a dependency created between Kernel A and Kernel B

MOVING DATA



- Here both kernel functions are enqueued to the same device, in this case a GPU
- The data must be copied to the GPU before the Kernel A is executed
- The data must remain on the GPU for Kernel B to be executed
- The data must be copied back to the host after Kernel B has executed

DATA FLOW



- Combining kernel function dependencies and the data movement dependencies we have a final data flow graph
- This graph defines the order in which all commands must execute in order to maintain consistency
- In more complex data flow graphs there may be multiple orderings which can achieve the same consistency

DATA FLOW WITH BUFFERS AND ACCESSORS

```
sycl::buffer buf {data, sycl::range{1024}};

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor acc {buf, cgh};

  cgh.parallel_for<kernel_a>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      acc[idx] = /* some computation */
    });
});

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor acc{buf, cgh};

  cgh.parallel_for<kernel_b>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      acc[idx] = /* some computation */
    });
});

gpuQueue.wait();
```

- The buffer/accessor data management model data model is descriptive
- Dependencies and data movement is inferred from the access requirements of command groups
- The SYCL runtime is responsible for guaranteeing that data dependencies and consistency are maintained

DATA FLOW WITH BUFFERS AND ACCESSORS

```
sycl::buffer buf {data, sycl::range{1024}};

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor acc {buf, cgh};

  cgh.parallel_for<kernel_a>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      acc[idx] = /* some computation */
    });
});

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor acc {buf, cgh};

  cgh.parallel_for<kernel_b>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      acc[idx] = /* some computation */
    });
});

gpuQueue.wait();
```

- A `buffer` object is responsible for managing data between the host and one or more devices
- It is also responsible for tracking dependencies on the data it manages
- It will also allocating memory and move data when necessary.
- Note that a `buffer` is lazy and will not allocate or move data until it is asked to

DATA FLOW WITH BUFFERS AND ACCESSORS

```
sycl::buffer buf {data, sycl::range{1024}};

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor acc{buf, cgh};

  cgh.parallel_for<my_kernel>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      acc[idx] = /* some computation */
    });
});

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor acc{buf, cgh};

  cgh.parallel_for<my_kernel>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      acc[idx] = /* some computation */
    });
});

gpuQueue.wait();
```

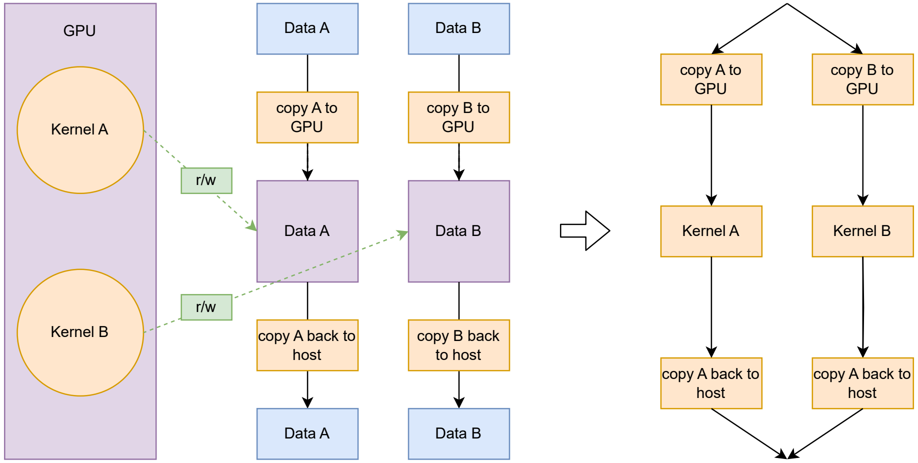
- An `accessor` object is responsible for describing data access requirements
- It describes what data a kernel function is accessing and how it is accessing it
- The `buffer` object uses this information to create infer dependencies and data movement

DATA FLOW WITH BUFFERS AND ACCESSORS

```
buf = sycl::buffer(data, sycl::range{1024});

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor acc {buf, cgh};

  cgh.parallel_for<my_kernel>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      acc[idx] = /* some computation */
    });
});

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor acc {buf, cgh};

  cgh.parallel_for<my_kernel>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      acc[idx] = /* some computation */
    });
});

gpuQueue.wait();
```

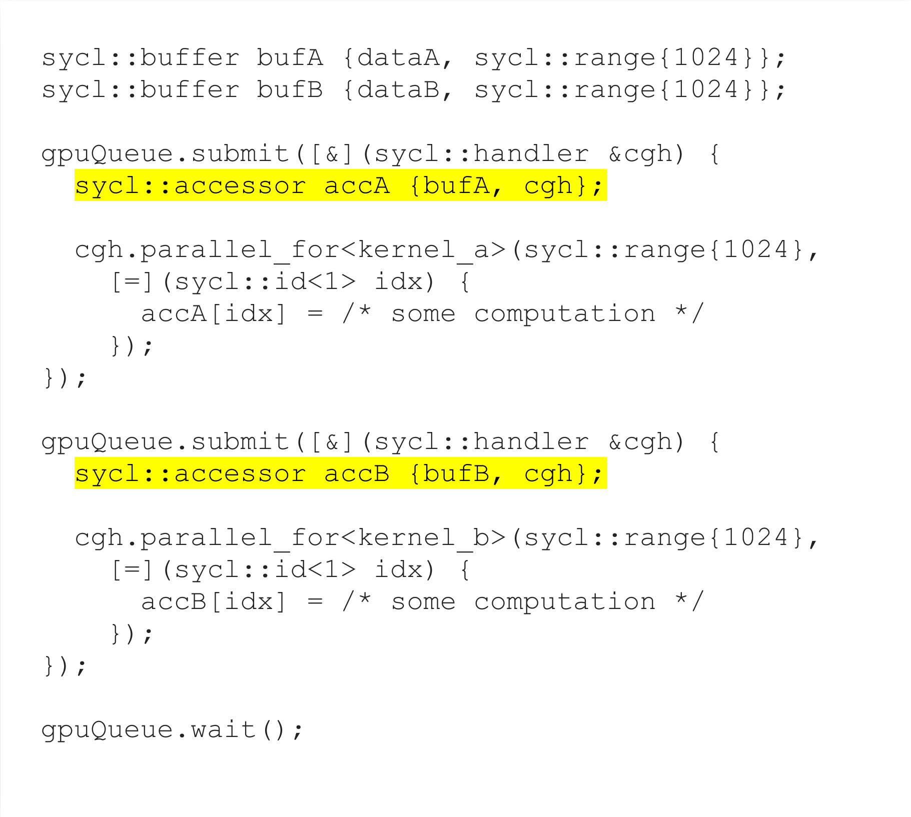
- Associating the `accessor` object with the `handler` connects the access dependency to the kernel function
- It also associates the access requirement with the device being targeted

CONCURRENT DATA FLOW



- If two kernels are accessing different buffers then there is no dependency between them
- In this case the two kernels and their respective data movement are independent
- By default queues are out-of-order which means that these commands can execute in any order
- They could also execute concurrently if the target device is able to do so

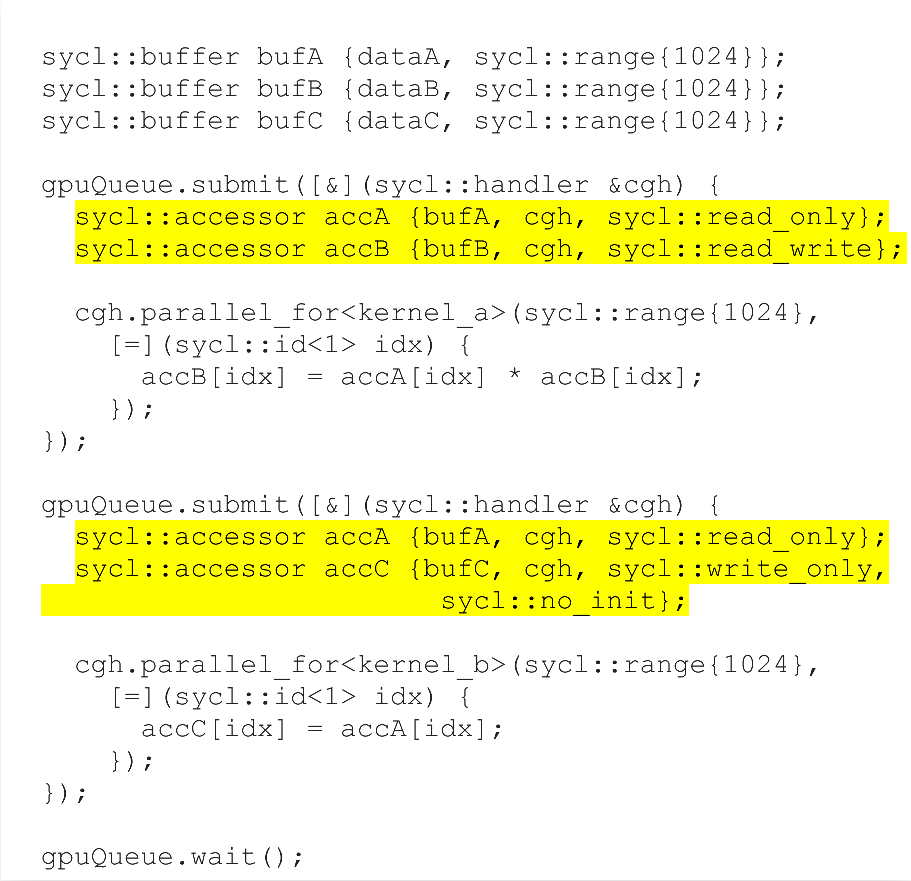
CONCURRENT DATA FLOW WITH BUFFERS AND ACCESSORS



```
sycl::buffer bufA {dataA, sycl::range{1024}};
sycl::buffer bufB {dataB, sycl::range{1024}};

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor accA {bufA, cgh};

  cgh.parallel_for<kernel_a>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      accA[idx] = /* some computation */
    });
});

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor accB {bufB, cgh};

  cgh.parallel_for<kernel_b>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      accB[idx] = /* some computation */
    });
});

gpuQueue.wait();
```

- The buffer/accessor data management model automatically infers dependencies
- As each of the two kernel functions are accessing different `buffer` objects the SYCL runtime can infer there is no dependency between them
- Data movement is still performed for the two kernels as normal
- The two kernels and their respective copies collectively can be executed in any order

BUFFER ACCESSOR MODES



```
sycl::buffer bufA {dataA, sycl::range{1024}};
sycl::buffer bufB {dataB, sycl::range{1024}};
sycl::buffer bufC {dataC, sycl::range{1024}};

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor accA {bufA, cgh, sycl::read_only};
  sycl::accessor accB {bufB, cgh, sycl::read_write};

  cgh.parallel_for<kernel_a>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      accB[idx] = accA[idx] * accB[idx];
    });
});

gpuQueue.submit([&](sycl::handler &cgh) {
  sycl::accessor accA {bufA, cgh, sycl::read_only};
  sycl::accessor accC {bufC, cgh, sycl::write_only,
                        sycl::no_init};

  cgh.parallel_for<kernel_b>(sycl::range{1024},
    [=](sycl::id<1> idx) {
      accC[idx] = accA[idx];
    });
});

gpuQueue.wait();
```

- Access modes help optimise the dependency graph
- Both kernels access buffer A; B and C are only accessed by one kernel each
- The A-accessors are marked read-only, so the kernels are independent
- B and C are written to; C is write-only and does not need it's initial data copied in.
- These kernels can now run concurrently despite both accessing buffer A

WHICH SHOULD YOU CHOOSE?

When should you use the buffer/accessor or USM data management models?

Buffer/accessor data movement model

- If you want to guarantee consistency and avoid errors
- If you want to iterate over your data flow quicker

USM data movement model

- If you need to use USM
- If you want more fine grained control over data movement

QUESTIONS

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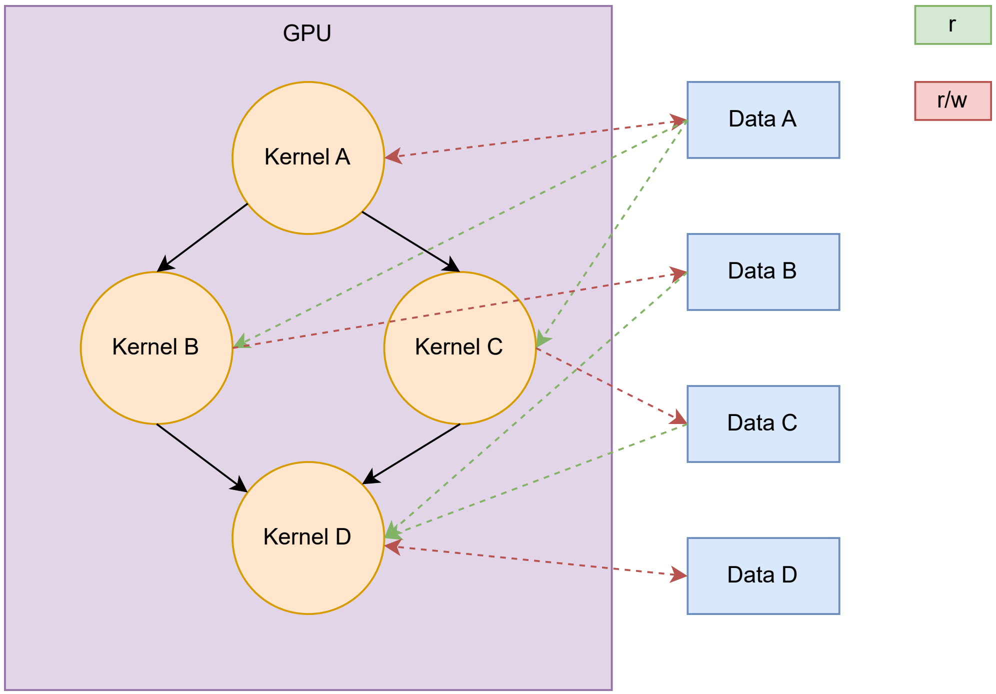
EXERCISE

Code_Exercises/Data_and_Dependencies/source



Put together what you've seen here to create the above diamond data flow graph using the buffer/accessor data management model

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