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Enabling the Use of C++20 Unseq Execution Policy for OpenCL

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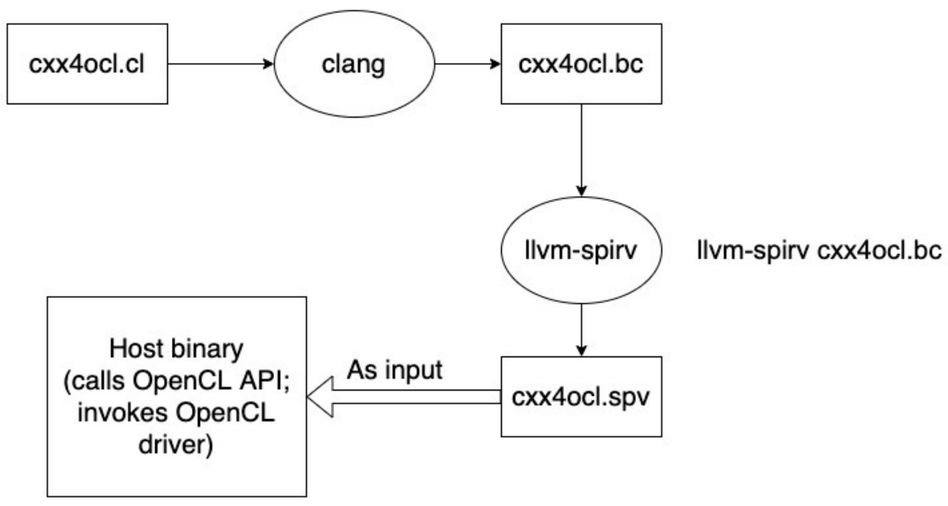
Motivation

- C++ for OpenCL was announced in 2020, but without the support of the standard library as stated in the C++ standard.
- We explore the use of execution policy as in the C++ parallel library (focused on execution::unseq from C++20).
- Inspired by OpenCL vector, this paper supports C++ template of execution::unseq based on OpenCL vector.

Compilation Flow

C++ for OpenCL compilation flow

clang -cl-std=clc++ -Xclang -finclude-default-header -target spir64 -emit-llvm -c cxx4ocl.cl



Unseq with OpenCL Vector

- This for_each call may be vectorized.

```
std::for_each(std::execution::unseq, base_ptr, base_ptr +
      1024 * 1024, [&](auto& v) {
  v = a[idx] + b[idx];
});
```

- OpenCL vector are mapped to LLVM vector in LLVM IR layer.

```
%29 = add nsw i32 %28, %26          ; scalar addition
%29 = add nsw <4 x i32> %28, %26    ; OpenCL vector (int4)
      addition
```

Procedural Steps

Step1 Define unseq object

This step defines the types as follows and a global object unseq of type unsequenced_policy accordingly.

```
struct unsequenced_policy {};
struct sequenced_policy {};
constexpr unsequenced_policy unseq{};
```

Step2 OpenCL kernel with execution policy

Overload functions with execution policy types.

```
__kernel void vadd(__global DataTy const* a, __global
    DataTy const* b, __global DataTy* c) {
  auto idx = get_global_id(0);
  auto base_ptr = c + idx;
  std::for_each(std::execution::unseq, base_ptr, base_ptr
      + 1024 * 1024, [&](auto& v) {
    v = a[idx] + b[idx];
  });
}
```

Step3 Using directive to vector

- Clang would then inline the function object call operator as in f(*first) and vectorize the loop with clang directive.
- The resulting LLVM bitcode would contain LLVM vector types .
- OpenCL vector types also get lowered to LLVM vector type.

```
template <typename ForwardIterator, typename Function>
Function for_each(execution::unsequenced_policy exec,
                  ForwardIterator first,
                  ForwardIterator last, Function f) {
#pragma clang loop vectorize(enable) vectorize_width(
    VEC_WIDTH)
  for (; first != last; ++first)
    f(*first);
  return f;
}
```

Experimental Results

Experiment Environments

Platform:
- OpenCL 2.1
- Clang 10.0.1
- Spirv translator: llvm-spirv (built against LLVM 10.0.1)

OpenCL devices:
- Intel(R) CPU Runtime for OpenCL(TM) Applications/Intel(R) Core(TM) i7-7700 CPU @ 3.60GHz
- Intel(R) OpenCL HD Graphics/Intel(R) Gen9 HD Graphics NEO

- In the case of SAD on GPU, vector width 4 results in a speedup of 3.4, and vector width 16 results in 6.9X speedup