Implementing ParallelSTL
using SYCL

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Codeplay Research

Who am I

Ruyman Reyes, Ph.D

- R&D Runtime Engineer, Codeplay
  → SYCL runtime and spec. contributor.
- > 5 years expr. HPC
  → BSC, EPCC among others
- Research in P.M. for Heterogeneous Computing
  → OpenMP, OMPSs, OpenAcc


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Overview

1. Background
2. The N4409 Proposal
3. A **SYCL**-based Parallel STL

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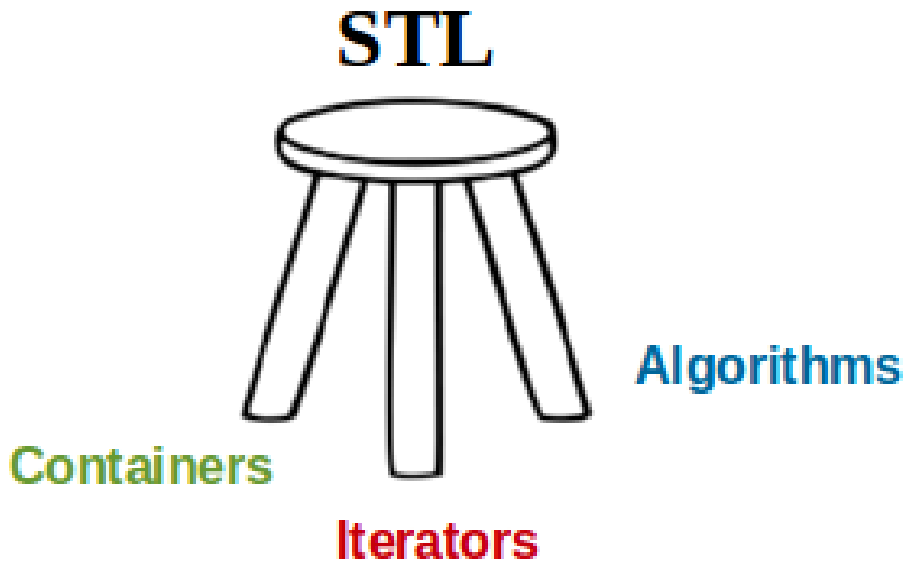
Background

STL - C++ Standard Template Library

- Widely used algorithm/container library
- Template-based to enable compile-time optimizations
- Any container can be used on any algorithm via iterators



Using the STL

Using vectors, lists and algorithms

```
std::vector<int> myVector = { 8, 9, 1, 4 };
std::list<int> myList;
// Insert something at the end of the vector
myVector.push_back(33);
// Sort the vector
std::sort(myVector.begin(), myVector.end());
// Check that myVector is sorted
if (std::is_sorted(std::begin(myVector), std::end(myVector)))
    {
  std::cout << " Data is sorted! " << endl;
}
// Copy elements larger than 10
std::copy_if(std::begin(myVector), std::end(myVector),
             std::back_inserter(myList),
    [](int i){ return  (i>10); });
// The list should only have one element
std::cout << " List size :"  << myList.size() << std::endl;
```

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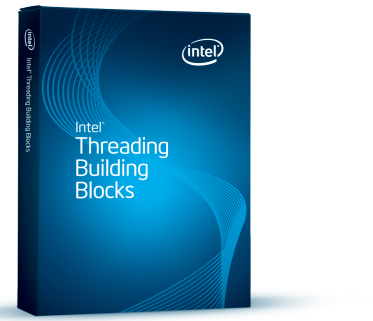
Parallel libraries in Heterogeneous computing

BOLT

- Each vendor has its own parallel-algorithm library
- Interface resembles STL but different
- Makes code platform specific!



Thrust

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The N4409 Proposal

Parallel STL: Democratizing Parallelism in C++

- Group of software engineers from Intel, Microsoft and Nvidia
  → Based on TBB (Intel), PPL/C++AMP (MS), Thrust (Nvidia)
- Working draft for C++17 N4409
  → Previously: N3554, N3850, N3960, N4071
  → Describes an interface to algorithms with parallel execution
  → Perform parallel operations on generic containers
- Extends the current STL interface with policies allowing parallel execution.

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- Extends the current STL interface with policies allowing parallel execution.

This is still not part of the C++ standard

This is a work-in-progress proposal for the upcoming C++17

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Sorting with the STL

A sequential sort

```
std::vector<int> data = { 8, 9, 1, 4 };
std::sort(data.begin(), data.end());
if (std::is_sorted(data)) {
   cout << " Data is sorted! " << endl;
}
```

Sorting with the STL

A parallel sort

```
std::vector<int> data = { 8, 9, 1, 4 };
std::experimental::parallel::sort(par, data.begin(), data.end
    ());
if (std::is_sorted(data)) {
    cout << " Data is sorted! " << endl;
}
```

- **par** is an *Execution Policy*
- Both the execution policy and sort iself are defined on the `experimental::parallel` namespace
  → Will be in std:: if approved

The Execution Policy

- Enables a standard algorithm to be potentially executed in parallel
  → Parallel execution is not guaranteed
- User is responsible of providing valid parallel code.
- Different libraries may have different policies

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Why not just a parallel implementation?

- Parallelism will not fit by default all problems
- Different algorithms may be better for different platforms
- Developer may want to use custom policies

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Default policies

Standard policy classes

- sequential_policy : *Never do parallel*
- parallel_execution_policy : *Do default parallelism*
- vector_execution_policy : *Use vectorisation if possible*
- execution_policy: *Dynamic execution policy*

Standard policy objects

```
extern const sequential_execution_policy seq;
extern const parallel_execution_policy par;
extern const vector_execution_policy vec;
```

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Using policies

```
using namespace std::experimental::parallel;
std::vector<int> vec = ...;
size_t threshold = 100u;

execution_policy exec = seq;

if (vec.size() > threshold) {
   exec = par;
}

sort(exec, vec.begin(), vec.end());
```

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Current implementations

- The Microsoft Codeplex Parallel STL
  https://parallelstl.codeplex.com/
- Thrust : Implement policies for algorithms
  https://thrust.github.io/

```
// sort data in parallel with OpenMP by specifying
// its execution policy
thrust::sort(thrust::omp::par, vec.begin(), vec.end());
```

- Some other implementations from the public avail. on github.
  → Search for Parallel STL !

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Algorithms

- The proposal slightly modifies some algorithms
  → `for_each` does not return the Functor again
- Some new algorithms are added
  → `for_each_n`
  → `inclusive_scan`, `exclusive_scan`
- Many of the already defined STL algorithms shall have the ExecutionPolicy overloads.
  → `copy_if`, `copy_n`, `remove`, ...

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A SYCL-based Parallel STL

Codeplay SYCL STL implementation

- Khronos Open Source License
- Available on Github:
  `https://github.com/KhronosGroup/SyclParallelSTL`
- Current basic implementation:
  - Policy mechanism in place
  - sort (bitonic if size is power of 2, seq on gpu otherwise)
  - parallel `transform`
  - parallel `for_each`

Plenty of opportunities for your contribution!

- Implement more functions
- Improve algorithms
- Suggestions on the interface (e.g. Device-side vector?)

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Sorting with the STL

A sequential sort

```
vector<int> data = { 8, 9, 1, 4 };
sort(data.begin(), data.end());
if (is_sorted(data)) {
    cout << " Data is sorted! " << endl;
}
```

Sorting with the STL

Sorting on the GPU!

```
vector<int> data = { 8, 9, 1, 4 };
sycl::sort(sycl_policy, v.begin(), v.end());
if (is_sorted(data)) {
    cout << " Data is sorted! " << endl;
}
```

Sorting with the STL

Sorting on the GPU!

```
vector<int> data = { 8, 9, 1, 4 };
sycl::sort(sycl_policy, v.begin(), v.end());
if (is_sorted(data)) {
    cout << " Data is sorted! " << endl;
}
```

- **sycl_policy** is an *Execution Policy*
- **data** is an standard stl::vector
- Technically will use the device returned by *default_selector*

The SYCL Policy

```
template <typename KernelName = DefaultKernelName>
class sycl_execution_policy {
  public:

   using kernelName = KernelName;

   sycl_execution_policy() = default;
   sycl_execution_policy(cl::sycl::queue q);
   cl::sycl::queue get_queue() const;
};
```

- Indicates algorithm will be executed using a SYCL-device
- Can optionally take a queue
  - → Re-use device-selection
  - → Asynchronous data copy-back
  - → ...

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Why the KernelName template?

Two separate calls can generate different kernels!

```
transform(par, v.begin(), v.end(), [=](int& val){ val++; });
transform(par, v.begin(), v.end(), [=](int& val){ val--; });
```

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Why the KernelName template?

Two separate calls can generate different kernels!

```
transform(par, v.begin(), v.end(), [=](int& val){ val++; });
transform(par, v.begin(), v.end(), [=](int& val){ val--; });
```

Why is this?

```
auto f = [vectorSize, &bufI, &bufO, op](cl::sycl::handler &h)
    mutable {
  ...
  auto aI = bufI.template get_access<access::mode::read>(h);
  auto aO = bufO.template get_access<access::mode::write>(h);
  h.parallel_for< /* The Kernel Name */>(r,
      [aI, aO, op](cl::sycl::id<1> id) {
          aO[id.get(0)] = UserFunctor(aI[id.get(0)]);
       });
};
```

Using named policies and queues

```
using namespace cl::sycl;
using namespace experimental::parallel::sycl;

std::vector<int> v = ...;
// Transform
default_selector ds;
{
 queue q(ds);
 sort(sycl_execution_policy(q), v.begin(), v.end());
 sycl_execution_policy<class myName> sepn1(q);
 transform(sepn1, v2.begin(), v2.end(),
                  v2.begin(), [=](int i) { return i + 1;});
}
```

- Only required for lambdas, not functors
- Device selection and queue are re-used
- Data is copied in/out in each call!

Avoiding data-copies using buffers

```
using namespace cl::sycl;
using namespace experimental::parallel::sycl;

std::vector<int> v = ...;
default_selector h;
{
  buffer<int> b(v.begin(), v.end());
  b.set_final_data(v.data());
  {
    cl::sycl::queue q(h);
    sort(sycl_execution_policy(q), begin(b), end(b));
    sycl_execution_policy sepn1(q);
   transform(sepn1, v2.begin(), v2.end(),
                  v2.begin(), [=](int i) { return i + 1;});
  }
}
```

- Buffer is constructed from STL containers
- Data will be copied back to the container when buffer is done
  → Note the additional copy from vec to buffer and viceversa

Using device-only data

```
using namespace experimental::parallel::sycl;
default_selector h;
{
  buffer<int> b(range<1>(size));
  b.set_final_data(v.data());
  {
    cl::sycl::queue q(h);
    {
      auto hostAcc = b.get_access<mode::read_write,
                                  target::host_buffer>();
      for (auto & : hostAcc) {
        *i = read_data_from_file(...);
      }
    }
    sort(sycl_execution_policy(q), begin(b), end(b));
    transform(sycl_policy, begin(b), end(b), begin(b),
                       std::negate<int>());
  }
}
```

- Data is initialized in the host using a host accessor
- After host accessor is done, data is on the device

SYCL/STL interop functions

Defined in SYCL

- Buffer constructor taking `begin`/`end`
- `set_final_data` taking `begin`/`end`

Extended by SYCL STL

- Host and Buffer iterators
- `begin`/`end` functions

Remember: You need an *accessor* to read data from buffers!

Final Remarks

If you have any questions or comments...

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