An Introduction to the Thrust Parallel Algorithms Library

What is Thrust?

- High-Level Parallel Algorithms Library
- Parallel Analog of the C++ Standard Template Library (STL)
- Performance-Portable Abstraction Layer
- Productive way to program CUDA

Example

```
#include <thrust/host_vector.h>
#include <thrust/device_vector.h>
#include <thrust/sort.h>
#include <cstdlib>

int main(void)
{
    // generate 32M random numbers on the host
    thrust::host_vector<int> h_vec(32 << 20);
    thrust::generate(h_vec.begin(), h_vec.end(), rand);

    // transfer data to the device
    thrust::device_vector<int> d_vec = h_vec;

    // sort data on the device
    thrust::sort(d_vec.begin(), d_vec.end());

    // transfer data back to host
    thrust::copy(d_vec.begin(), d_vec.end(), h_vec.begin());

    return 0;
}
```

Easy to Use

- Distributed with CUDA Toolkit
- Header-only library
- Architecture agnostic
- Just compile and run!

```
$ nvcc -O2 -arch=sm_20 program.cu -o program
```

Productivity

- Containers

  `host_vector`

  `device_vector`

- Memory Mangement
  - Allocation
  - Transfers
- Algorithm Selection
  - Location is implicit

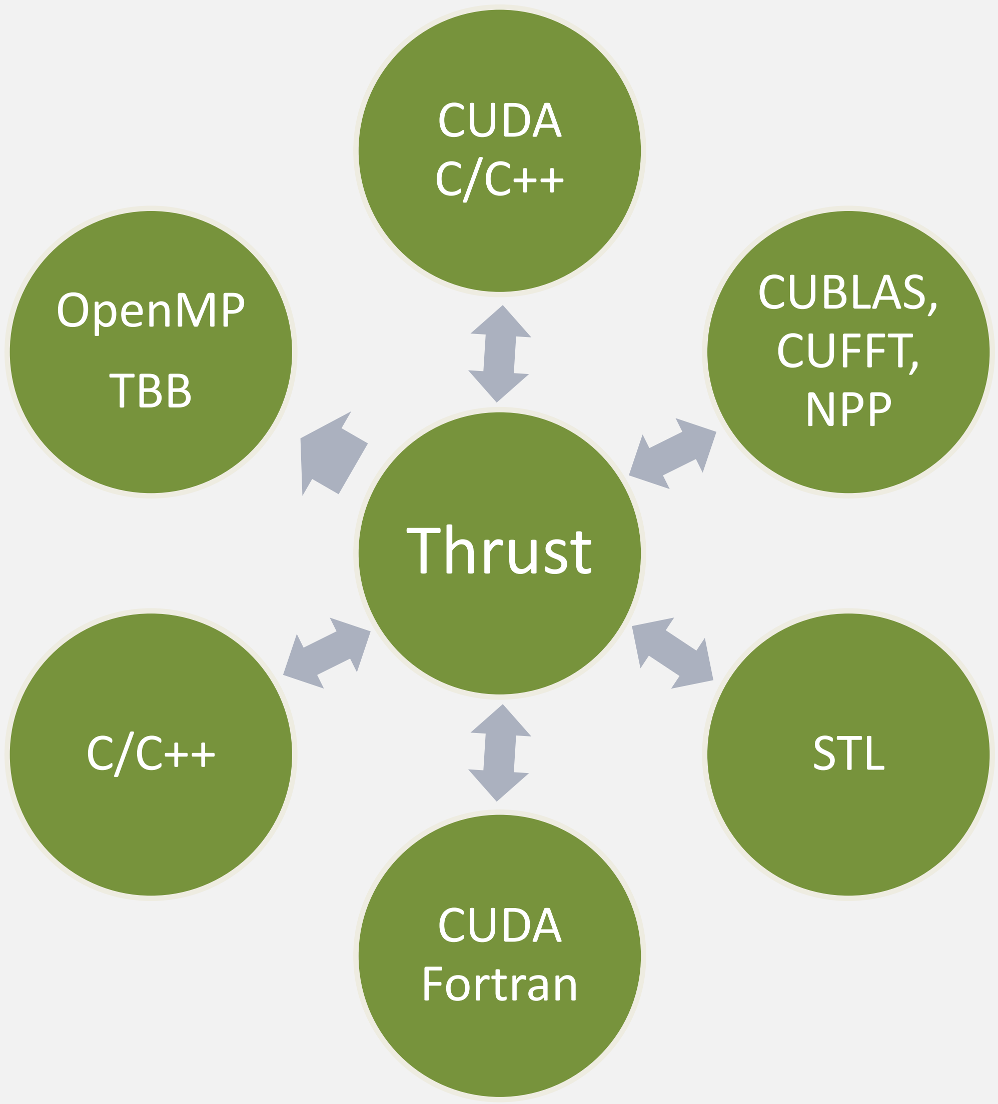
```
// allocate host vector with two elements
thrust::host_vector<int> h_vec(2);

// copy host data to device memory
thrust::device_vector<int> d_vec = h_vec;

// write device values from the host
d_vec[0] = 27;
d_vec[1] = 13;

// read device values from the host
int sum = d_vec[0] + d_vec[1];

// invoke algorithm on device
thrust::sort(d_vec.begin(), d_vec.end());

// memory automatically released
```

Productivity

- Large set of algorithms
  - ~75 functions
  - ~125 variations
- Flexible
  - User-defined types
  - User-defined operators

Algorithm	Description
`reduce`	Sum of a sequence
`find`	First position of a value in a sequence
`mismatch`	First position where two sequences differ
`inner_product`	Dot product of two sequences
`equal`	Whether two sequences are equal
`min_element`	Position of the smallest value
`count`	Number of instances of a value
`is_sorted`	Whether sequence is in sorted order
`transform_reduce`	Sum of transformed sequence

Interoperability



Portability

- Support for CUDA, TBB and OpenMP
  - Just recompile!

```
nvcc -DTHRUST_DEVICE_SYSTEM=THRUST_HOST_SYSTEM_OMP
```

NVIDA GeForce GTX 580

```
$ time ./monte_carlo
pi is approximately 3.14159

real    0m6.190s
user    0m6.052s
sys 0m0.116s
```

Intel Core i7 2600K

```
$ time ./monte_carlo
pi is approximately 3.14159

real    1m26.217s
user    11m28.383s
sys 0m0.020s
```

Backend System Options

Host Systems

`THRUST_HOST_SYSTEM_CPP`
`THRUST_HOST_SYSTEM_OMP`
`THRUST_HOST_SYSTEM_TBB`

Device Systems

`THRUST_DEVICE_SYSTEM_CUDA`
`THRUST_DEVICE_SYSTEM_OMP`
`THRUST_DEVICE_SYSTEM_TBB`

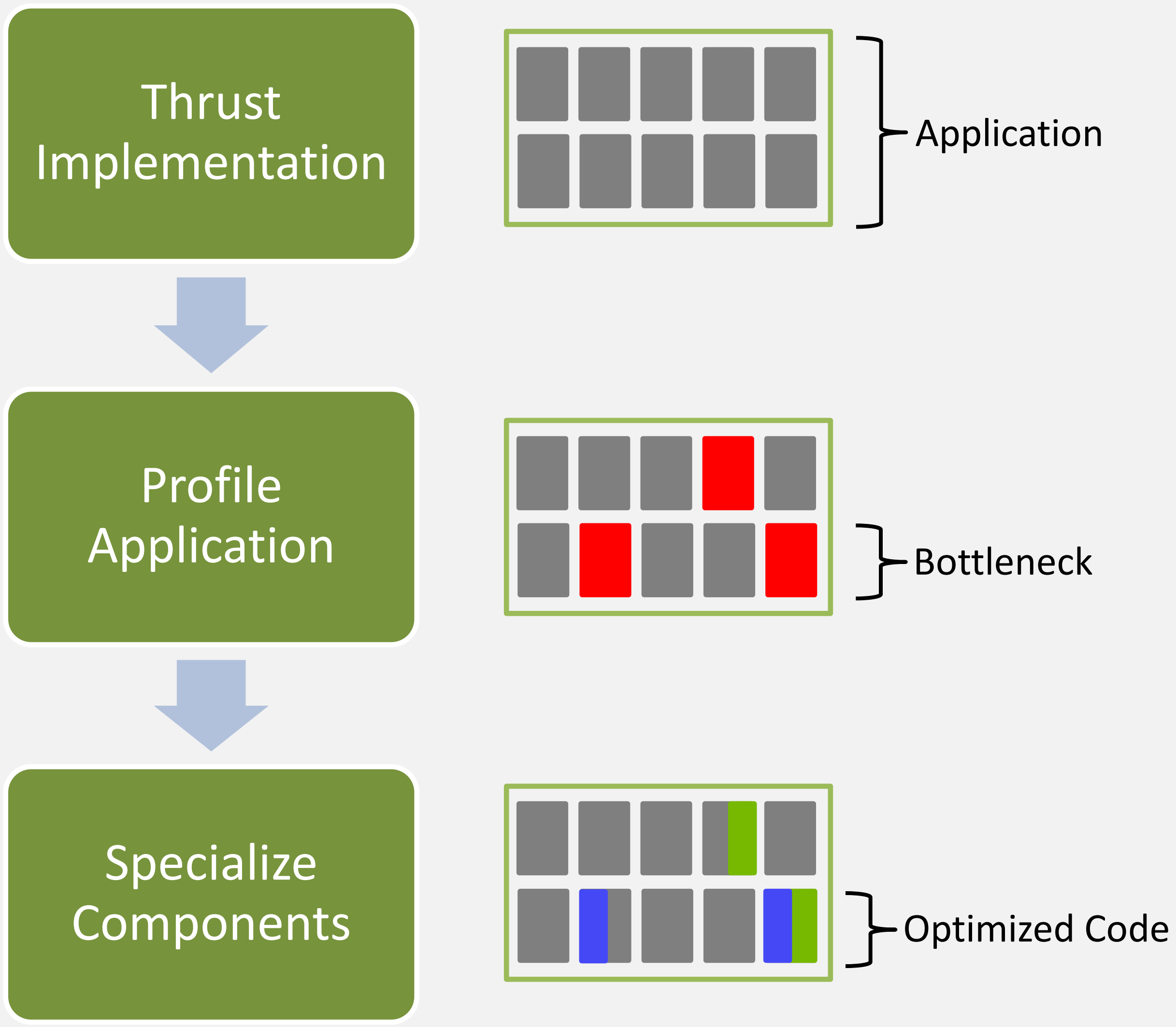
Multiple Backend Systems

- Mix different backends freely within the same app

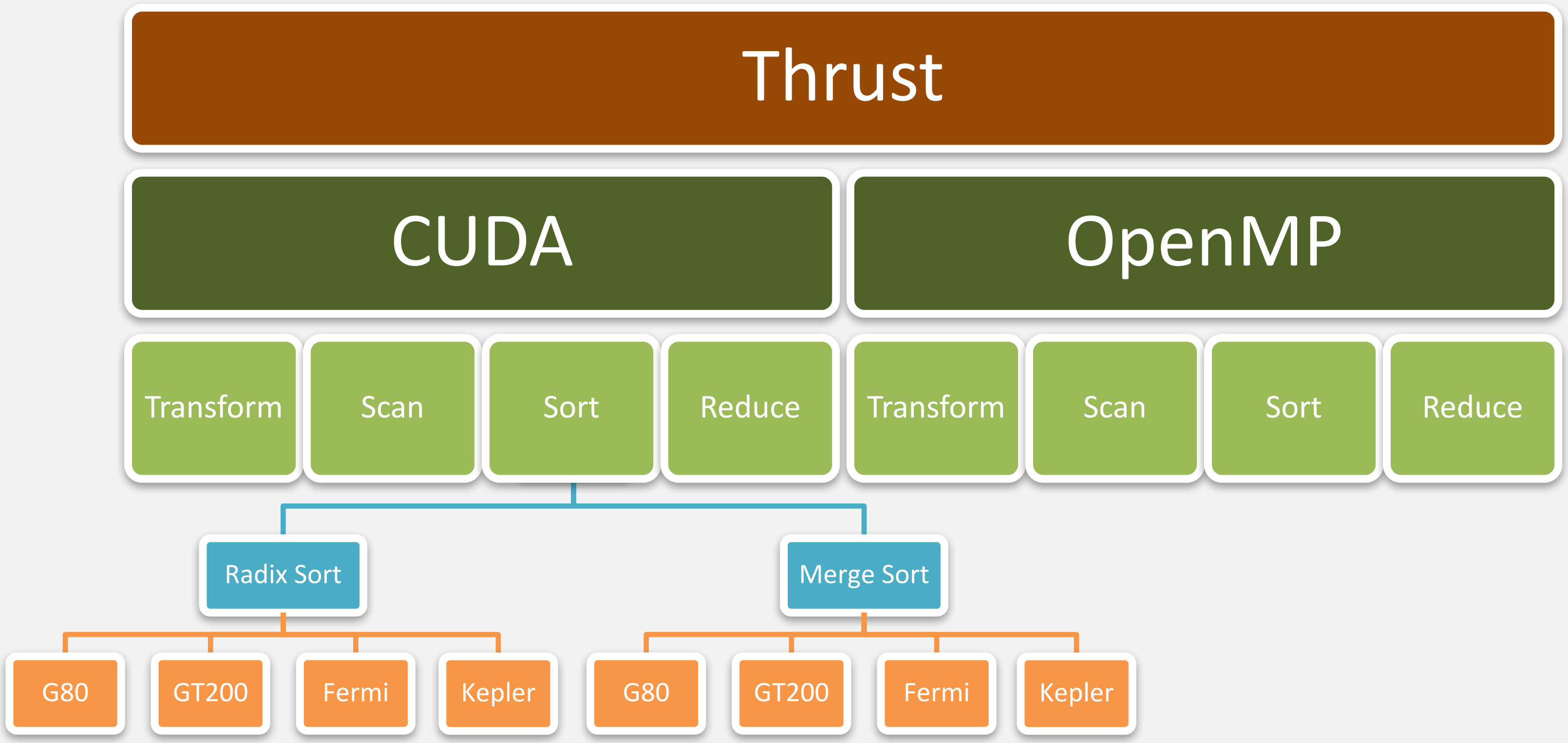
```
thrust::omp::vector<float> my_omp_vec(100);
thrust::cuda::vector<float> my_cuda_vec(100);

...

// reduce in parallel on the CPU
thrust::reduce(my_omp_vec.begin(), my_omp_vec.end());

// sort in parallel on the GPU
thrust::sort(my_cuda_vec.begin(), my_cuda_vec.end());
```

Potential Workflow

- Implement Application with Thrust
- Profile Application
- Specialize Components as Necessary



Performance Portability



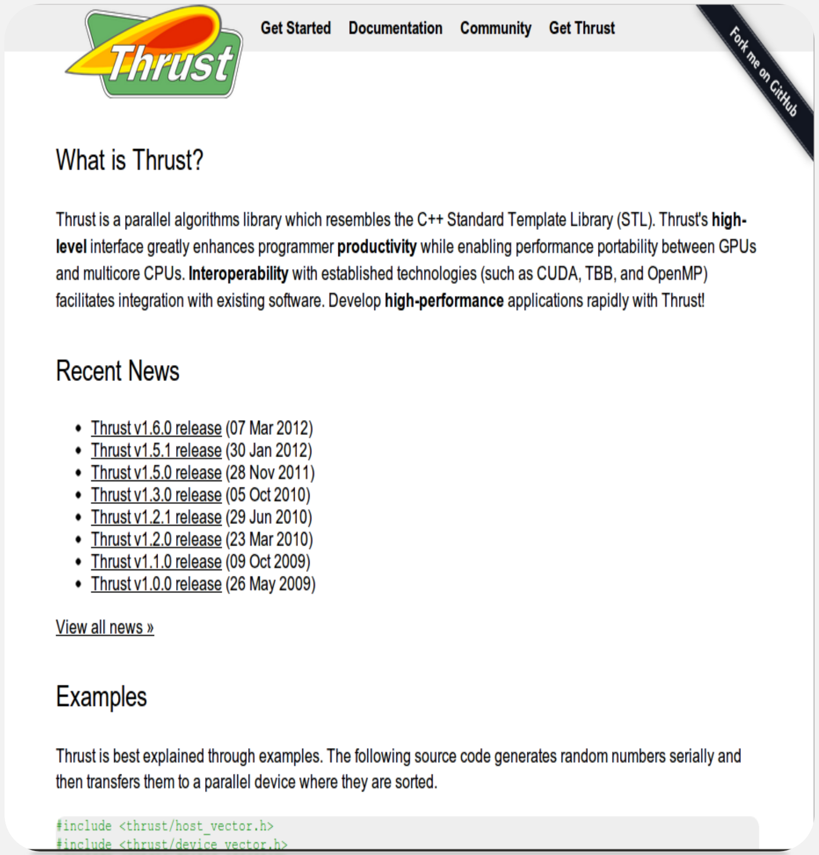
Robustness

- Reliable
  - Supports all CUDA-capable GPUs
- Well-tested
  - ~850 unit tests run daily
- Robust
  - Handles many pathological use cases

Openness

- Open Source Software
  - Apache License
  - Hosted on GitHub
- Welcome to
  - Suggestions
  - Criticism
  - Bug Reports
  - Contributions

thrust.github.com



What is Thrust?

Thrust is a parallel algorithms library which resembles the C++ Standard Template Library (STL). Thrust's **high-level** interface greatly enhances programmer **productivity** while enabling performance portability between GPUs and multicore CPUs. **Interoperability** with established technologies (such as CUDA, TBB, and OpenMP) facilitates integration with existing software. Develop **high-performance** applications rapidly with Thrust!

Recent News

- Thrust v1.6.0 release (07 Mar 2012)
- Thrust v1.5.1 release (30 Jan 2012)
- Thrust v1.5.0 release (28 Nov 2011)
- Thrust v1.3.0 release (05 Oct 2010)
- Thrust v1.2.1 release (29 Jun 2010)
- Thrust v1.2.0 release (23 Mar 2010)
- Thrust v1.1.0 release (09 Oct 2009)
- Thrust v1.0.0 release (26 May 2009)

View all news »

Examples

Thrust is best explained through examples. The following source code generates random numbers serially and then transfers them to a parallel device where they are sorted.

```
#include <thrust/host_vector.h>
#include <thrust/device_vector.h>
```

References

- Thomas Bradley – NVIDIA Corporation
  - https://developer.nvidia.com/cuda-education