Handling massive concurrency

Development of a programming model for GPU and CPU

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PUBLIC

Agenda

Our requirements and related concepts

The programming model

Results

Our requirements and related concepts

Context of the programming model

Llang compiler

- Just in time compiler in existing server environment using the LLVM backend
- Llang → internal language with little performance overhead compared to C++

Our requirements for the programming model

Ease-of-Use

Achieve comparable performance to CUDA

Write once

Supportability

Existing GPU programming models

OpenMP

- Sequential program
- Added pre-processor directives for parallelization

→Limited expressiveness as parallelization is „on top“ of programming language

Existing GPU programming models

CUDA

- Strong support for hardware capabilities
- Many libraries for special needs
- C-style interface, little abstraction

→Limited to Nvidia GPUs, no CPU execution possible

Existing GPU programming models

OpenCL

- Platform independent programming of highly parallel kernels
- Hardware abstraction
- Mature (but complex) interface, also in C++

→ Very close to what we need

→ No integration into existing environment

The programming model

Example usage of the programming model

```
_acc_kernel Void multiply(acc::GridInfo& gi, ForeignArray<Int32>& data) {
    Size index = gi.getThreadIdX() + gi.getBlockIdX() * gi.getThreadCountX();
    data[index] = data[index] * Int32(index);
}

export Void testMain() {
    Size blockCount = 32z;
    Size threadCount = 32z;
    ForeignArray<Int64> array = /*...*/;
    acc::GridConfig config(blockCount, threadCount);
    acc::gridInvoke(config, _bind(multiply, array));
}
```

Programming model – Kernel invocation

```
_acc_kernel Void multiply(acc::GridInfo& gi, ForeignArray<Int32>& data) { }
```

- Keyword `_acc_kernel`
- Function will be compiled for the CPU and GPU backend

```
acc::GridConfig config(blockCount, threadCount);
acc::gridInvoke(config, _bind(multiply, array));
```

- GridConfig to set number of threads and thread groups
- Kernel function bound with arguments

Programming model – Data transfer

```
acc::gridInvoke(config, _bind(multiply, array));
```

Data transfer handled by invoke mechanism

Programming model – Explicit data transfers

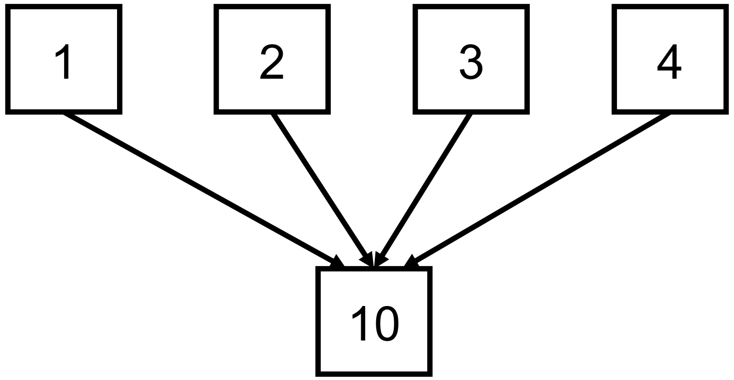
```
_acc_kernel Void multiply(acc::GridInfo& gi, ForeignArray<Int32>& data) {
}

export Void testMain() {
    Size blockCount = 32z;
    Size threadCount = 32z;
    ForeignArray<Int32> array = /*...*/;
    acc::Stream stream;
    {
        acc::GridConfig config(blockCount, threadCount);
        acc::Transfer arrayTransfer(array, stream);
        acc::gridInvoke(config, _bind(multiply, array), stream);
        acc::gridInvoke(config, _bind(multiply, array), stream);
    } // end of lifetime of transfer object triggers transfer
}
```

Programming model – Reduction

Aggregating multiple results into one, e.g. sum

```
_reduce(gridInfo, COMPLETE_GRID, partialResult, add, &result);
```



Programming model – Execution phases

Aim: Avoid self defined locks and dead locks

Concept: Have phases that are handled “sequentially”

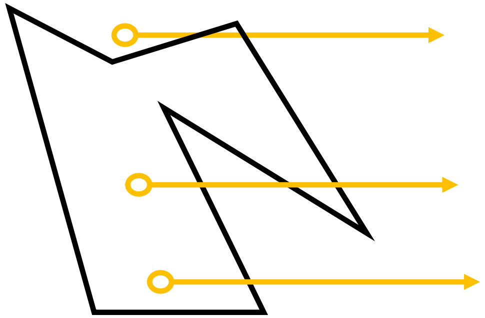
```
_acc_kernel Void kernel(acc::GridInfo& gi, ForeignArray<Int32> in, ForeignArray<Int32>& out) {
  _acc_shared ForeignArray<Int32> inShared;
  _acc_shared ForeignArray<Int32> outShared;
  _phased_execution "load" {
    // load data from in to inShared
  }
  _phased_execution "process" {
    // execution operation reading data from inShared and storing results in outShared
  }
  _phased_execution "aggregate" {
    // aggregate results in outShared
  }
}
```

Results

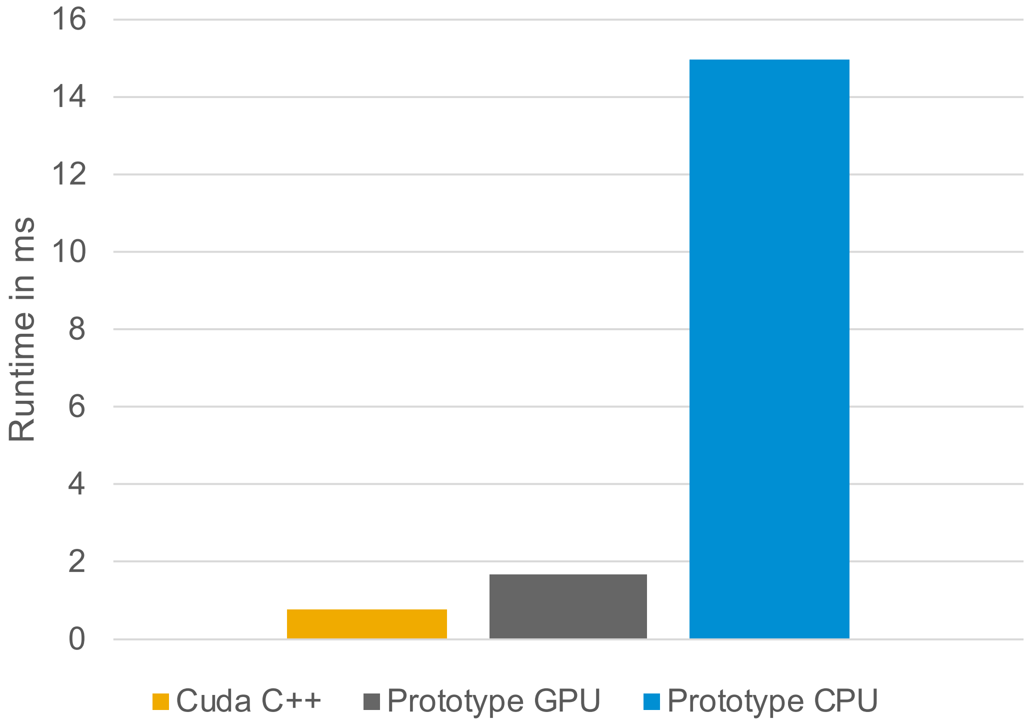
Points-in-polygon

For each point p:

- Count intersections of ray starting at p with polygon
- Even number: outside
- Odd number: inside



Kernel runtime
with 5’000 points and 10’000 edges
GPU: Nvidia Tesla P100
CPU: 4 x Intel Xeon E7-8880 v2 @2.5 GHz



Summary

Main concepts of our programming model

- Worker / kernel function like in CUDA / OpenCL
- Context object for multiple kernel calls (“Stream”); comparable to CUDA stream
- Object for kernel invocation configuration
- Object to handle explicit GPU transfer for an existing variable on CPU
- Execution phases to avoid explicit locks
- GPU and CPU backend with GPU focus

Thank you.

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