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Adding CUDA® Support to Cling: JIT Compile to GPUs

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ROOT Users' Workshop

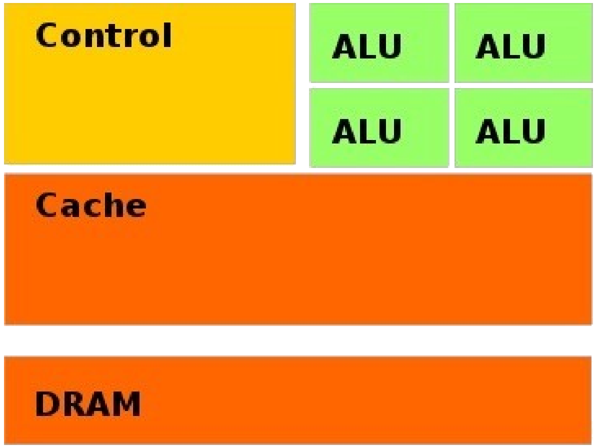
Parallelism, Heterogeneity and Distributed Data Processing

Sarajevo, September 10th 2018

Introduction

CPU/GPU Model

CPU



- Sources: Nvidia. *CUDA Reference Guide*

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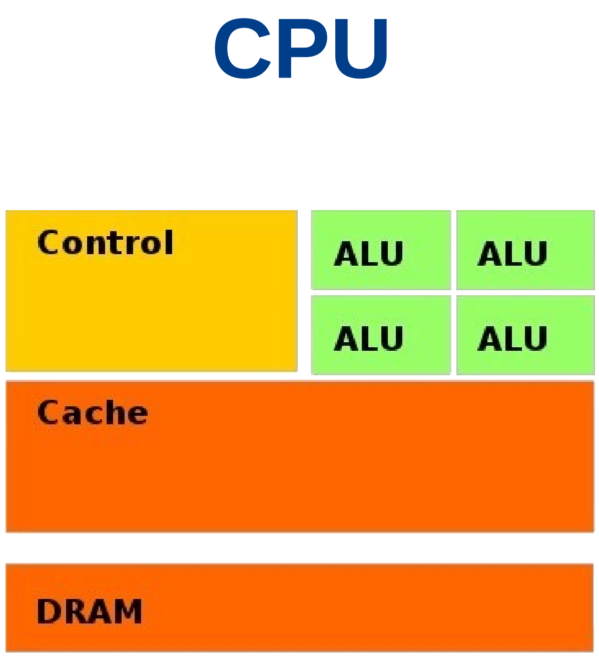

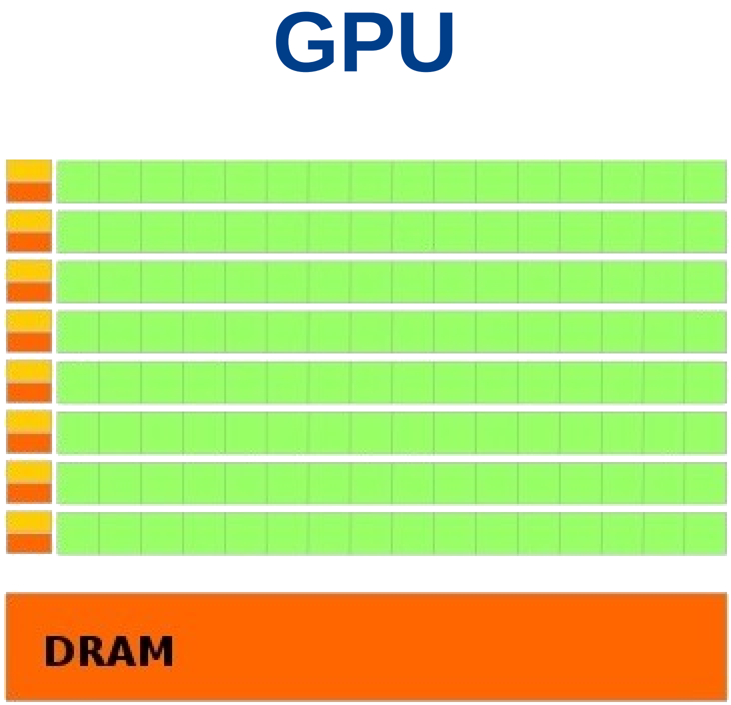

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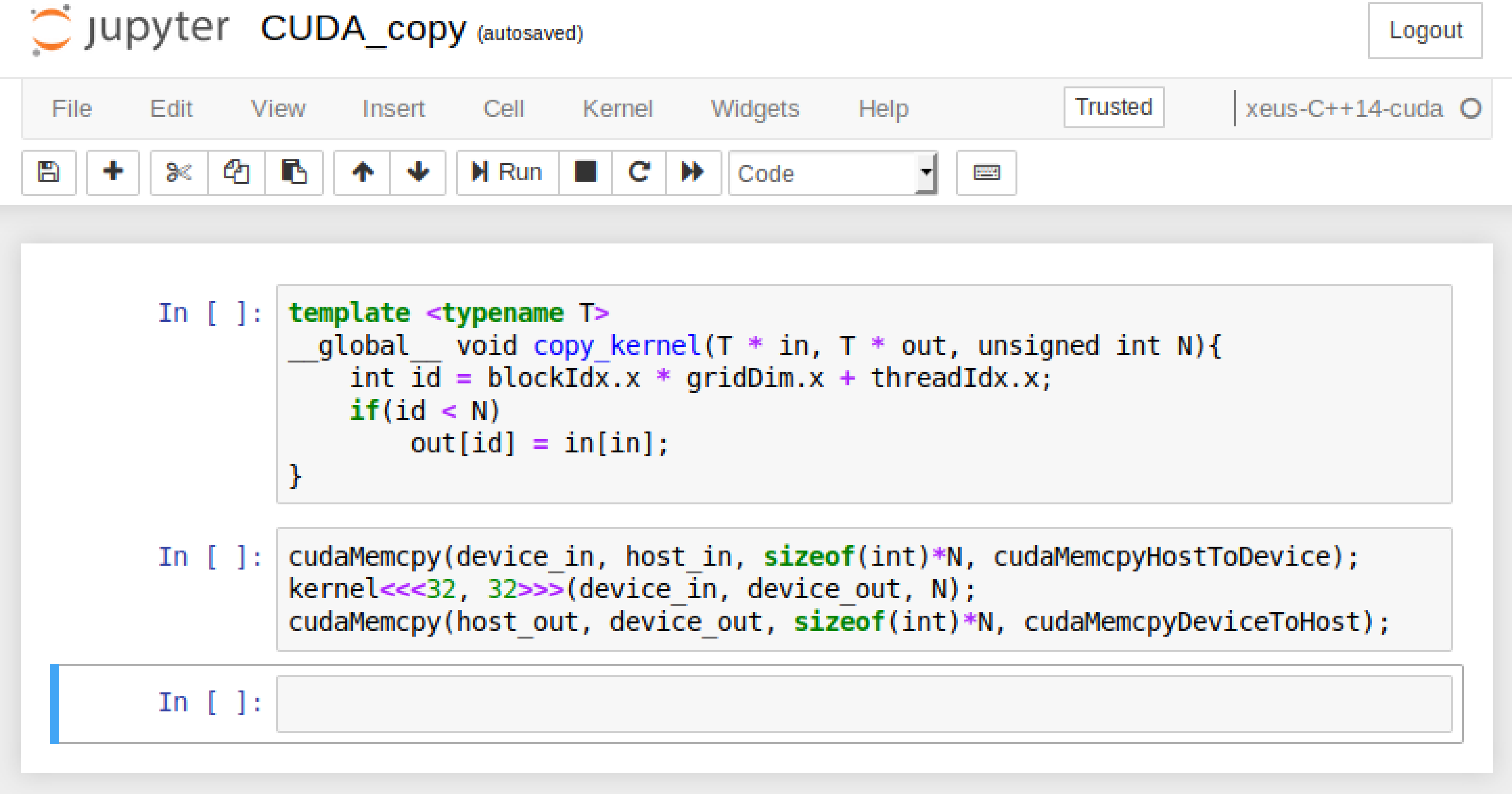
CUDA C++ in a Notebook: Runtime API



In [ ]:
```
template <typename T>
__global__ void copy_kernel(T * in, T * out, unsigned int N){
    int id = blockIdx.x * gridDim.x + threadIdx.x;
    if(id < N)
        out[id] = in[in];
}
```

In [ ]:
```
cudaMemcpy(device_in, host_in, sizeof(int)*N, cudaMemcpyHostToDevice);
kernel<<<32, 32>>>(device_in, device_out, N);
cudaMemcpy(host_out, device_out, sizeof(int)*N, cudaMemcpyDeviceToHost);
```

In [ ]:

How to use CUDA®

CUDA® source-code example

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//function, which will run on GPU
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__global__ void copy_kernel(T * in, T * out, unsigned int N){
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                out[id] = in[id];
}


int main(){

        // …

        // copy memory from cpu to gpu
        cudaMemcpy(device_in, host_in, sizeof(int) * N, cudaMemcpyHostToDevice);

        // start function on GPU with 32 threads an 10 blocks
        kernel<int><<<32, 10>>>(a, b, c);

        // copy memory from gpu to cpu
        cudaMemcpy(host_out, device_out, sizeof(int) * N, cudaMemcpyDeviceToHost);

        // …
}
```

CUDA® source-code example

Device-Code

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Host-Code

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CUDA® C/C++-APIs

Driver API

- C/C++-conform
- Host and Device-Code separated
- Compiling kernels via library functions during runtime
- Modifiable kernel possible

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    // …
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```
//special kernel launch syntax!
kernel<int><<<32, 10>>>(a, b, c)
```

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Runtime API

- Special syntax and semantic
- Single-Source-Design

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main.cu

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→ Cling needs modification

Implementation

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- Handle special syntax, semantic and **single-source design**
  - Enable Clang CUDA frontend[1] in Cling

[1] GPUCC - An Open-Source GPGPU Compiler CGO 16; nowadays mainline in Clang

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- Generating Device-Code during runtime
  - Develop second compiler pipeline
  - Rely on Clang CUDA Toolchain **up to PTX**
  - Couple via Nvidia “fatbinary”
  - Generate SASS code on Nvidia driver side

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- Cling-CUDA in Jupyter Notebook
  - standard kernel of **cling -x cuda**
  - using **xeus-cling** (patch to be upstreamed)

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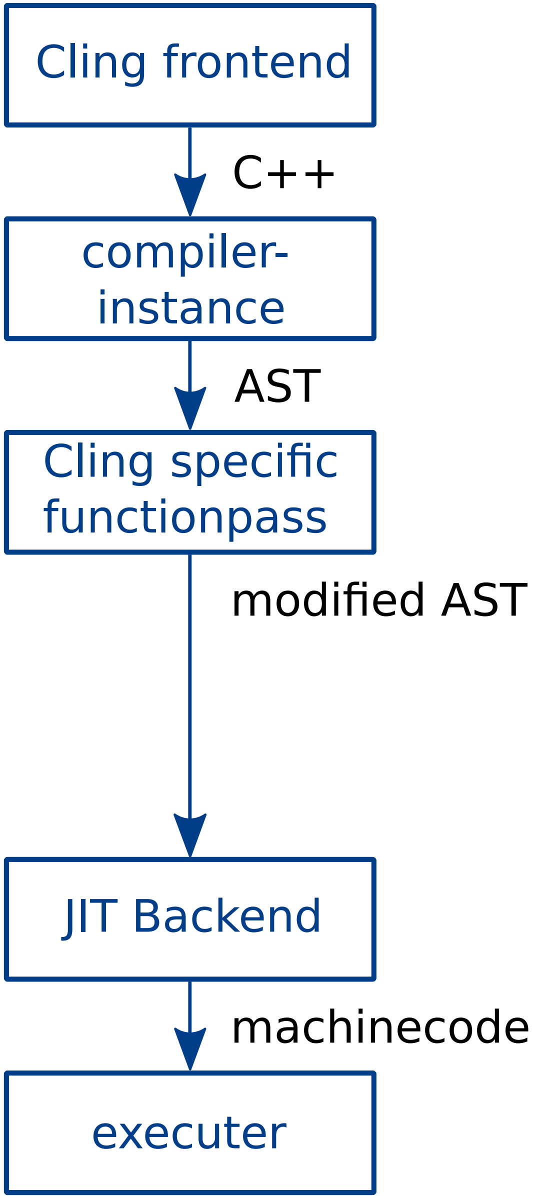
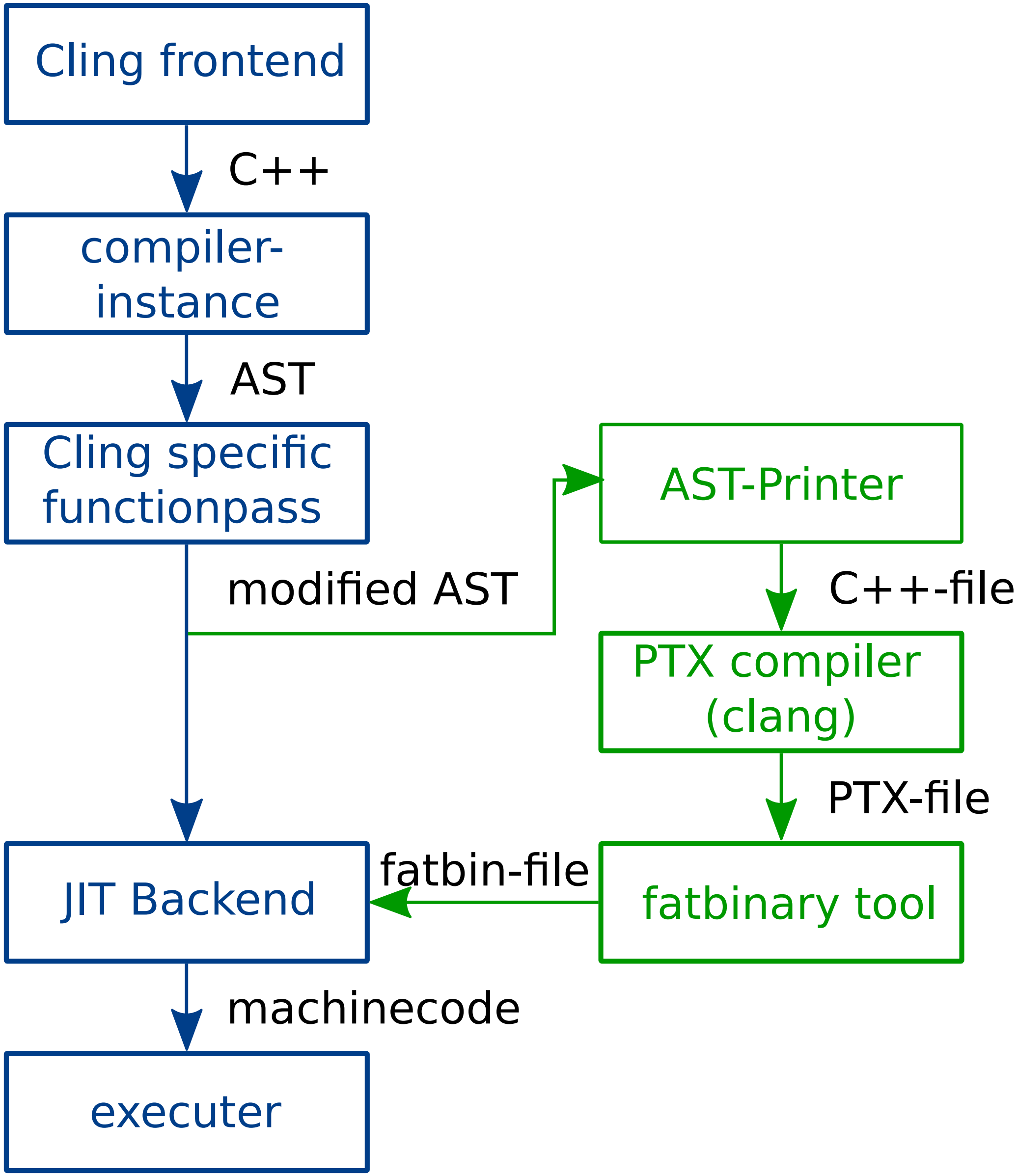
Cling-CUDA Compiler Pipeline



Cling-CUDA Compiler Pipeline



What is still missing

- Some C++ and CUDA statements, although supported by Clang 5.0 on CUDA 8.0
  - AST-Printer: variable __attributes__, structured bindings

AST-Printer failure examples

```
__device__ int var = 42;
```

↓

```
int var = 42 __attribute__((device));
```

```
// struct s { int x1 = 1; float x2 = 2.0f;}; s S;
auto [a, b] = S;
```

↓

```
auto = S
```

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- Kernel unloading
  - in contact with Nvidia about further documentation

- Cleanup
  - e.g. semantic detection of CUDA device functions

Summary

Initial CUDA Support in Cling

- First interpreter for the CUDA **runtime** API
  - Based on Clang CUDA toolchain, not cudafe

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- Easy access to HPC GPU systems via **Jupyter Notebook**
  - **Data analysis** in notebooks with GPUs
  - Big, **interactive simulation** with GPUs
  - **Teaching** GPU programming
  - Easing **development** and debugging
- **xeus-cling:** patched kernel for **cling -x cuda**