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TORNADO VM

A Brief Retrospective

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Aims

- How is Tornado different to *x, y,* and *z?*
- Is the motivation behind Tornado still applicable today?
- What is the performance story?

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How is Tornado different to *x*, *y*, and *z*?

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TORNADOVM

What is TornadoVM?

A virtual-machine in a virtual-machine that enables seamless execution across a range of heterogeneous architectures.

Now an open-source project at UoM.

tornadovm.org

github.com/beehive-lab/tornadovm

```java
void vectorAdd(int[] a, int[] b, int[] c){
    for(@Parallel int i=0; i<c.length; i++)
        c[i] = a[i] + b[i];
}

// execute add on an accelerator
 new TaskSchedule("s0")
    .task("t0", SimpleMath::vectorAdd, a, b, c)
    .execute();
```

```
new TaskSchedule("s0")
    .task("t0", Example::foo, a, b, c)
    .execute();
```

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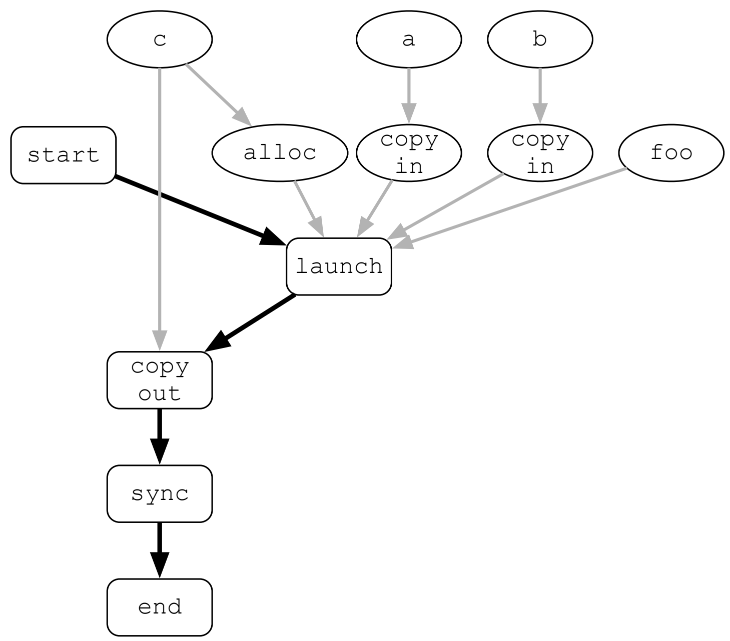

Generates a graph-IR that allows us to optimise both the data and the code that is to be executed.

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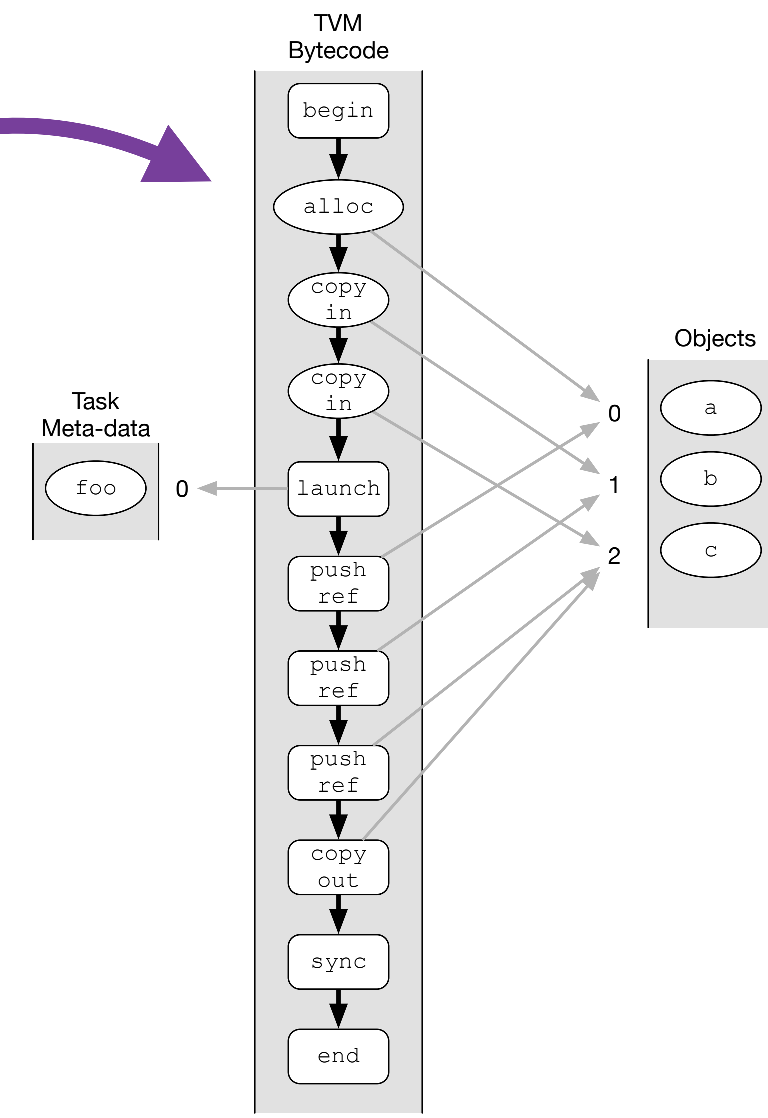
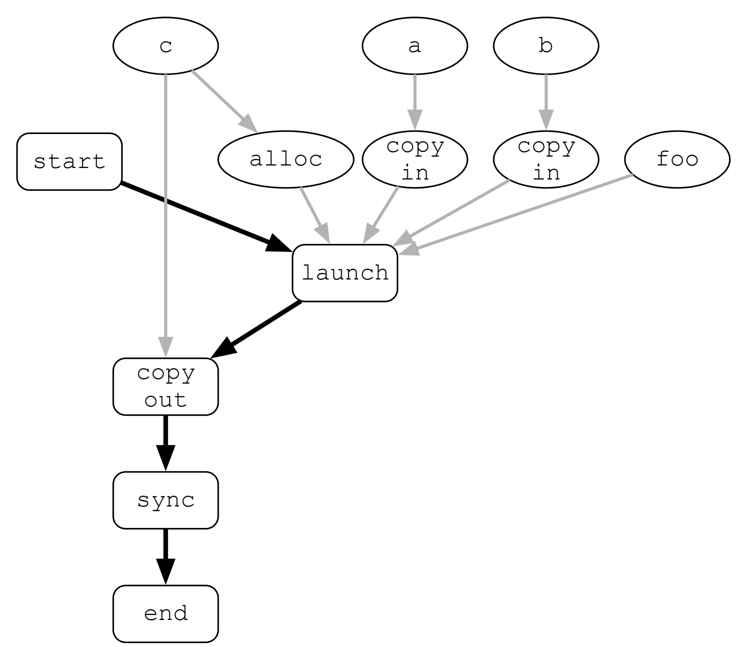
Graph-IR is compiled into bytecode and run on A Virtual Machine.





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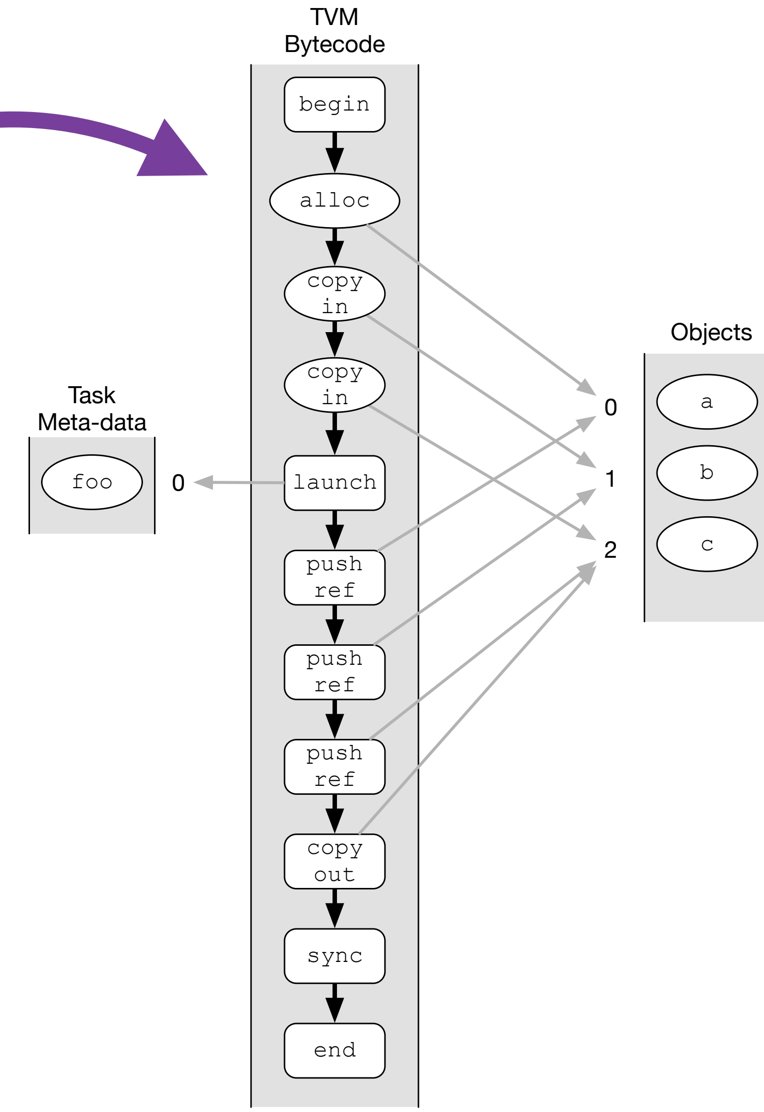

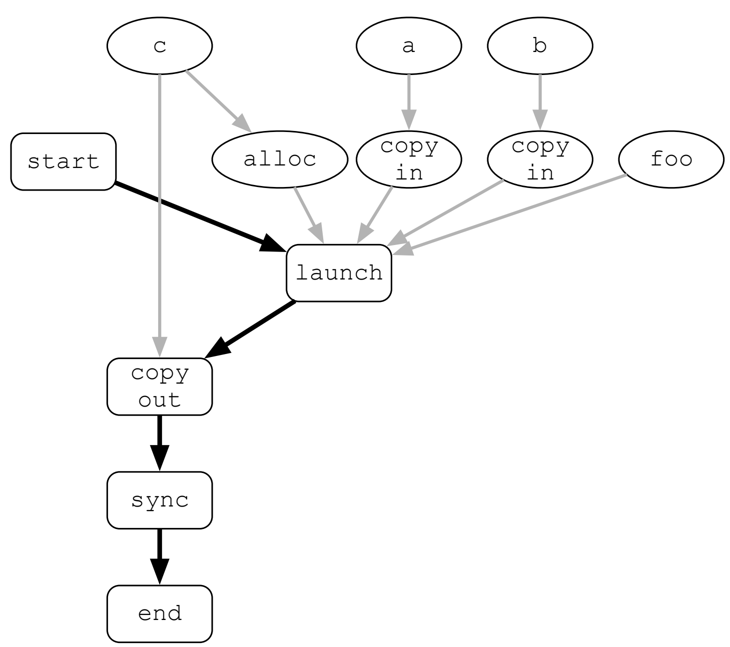

Generates a graph-IR that
allows us to optimise both the
data and the code that
is to be executed.

Each byte code performs an operation
on a disparate device.
e.g. copy memory to a GPGPU

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```java
// define a two stage pipeline
TaskSchedule schedule = new TaskSchedule("s0")
  .volatile(a)
  .task("t0", SimpleMath::vectorMultiply, a, b, c)
  .task("t1", SimpleMath::vectorAdd, c, b, d)
  .sync(d);


// query the number of devices attached to the system
TornadoDriver driver = getTornadoRuntime().getDriver(0);
int maxDevice = driver.getDeviceCount();
final Random rand = new Random(7);
final int[] devices = new int[2];

// invoke the pipeline multiple times
for (int i = 0; i < num_iterations; i++) {

  // randomly select a device for each task
  devices[0] = rand.nextInt(maxDevice);
  devices[1] = rand.nextInt(maxDevice);

  // update the task meta-data
  schedule.getTask("t0").mapTo(driver.getDevice(devices[0]));
  schedule.getTask("t1").mapTo(driver.getDevice(devices[1]));

  // execute the pipeline
  schedule.execute();
}
```

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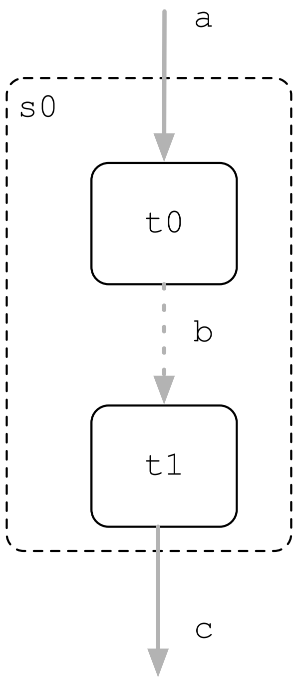

Two tasks running back-to-back on the same device.

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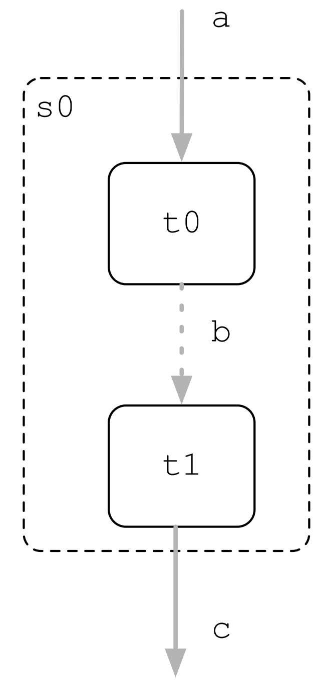

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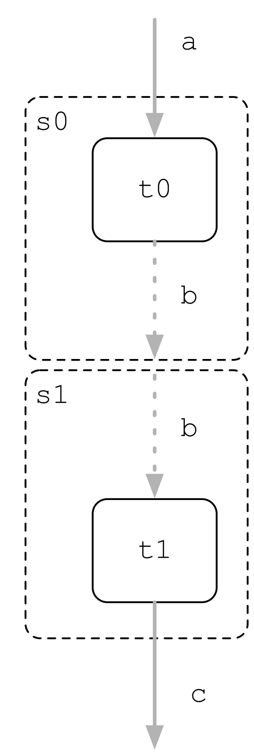

Two tasks running back-to-back on the different devices.

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Is the motivation behind Tornado still applicable today?

Rewind to 2010

Credit: Argonne National Laboratory [1]

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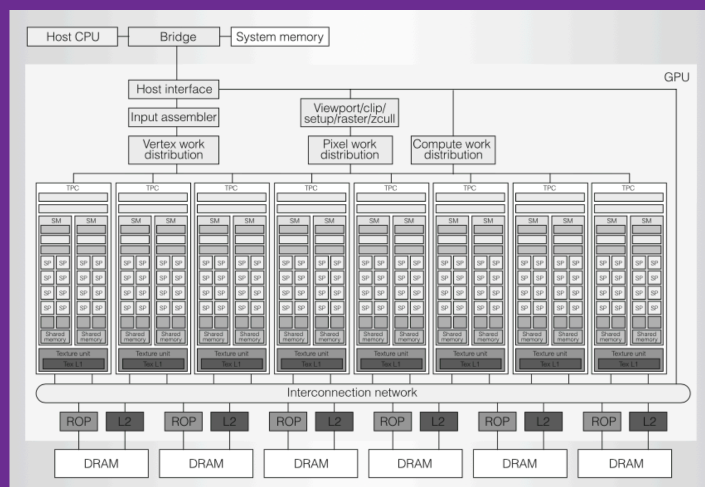
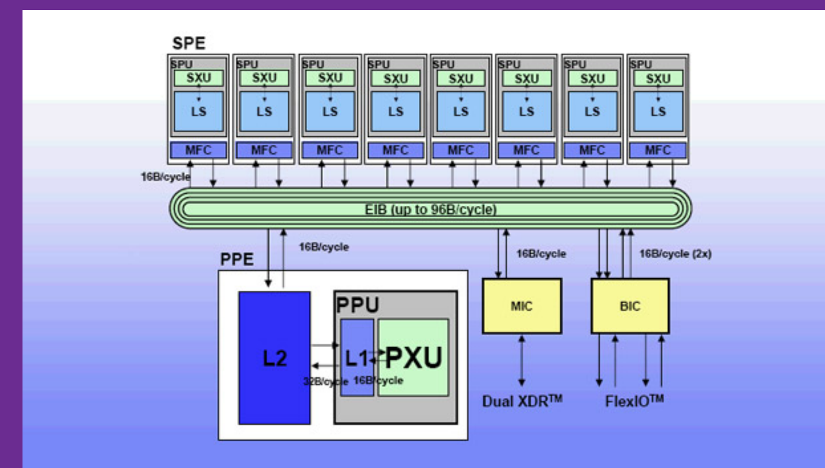
Innovation circa 2010

NVIDIA Tesla [3]



IBM Cell [5]



IBM PowerEN [2]

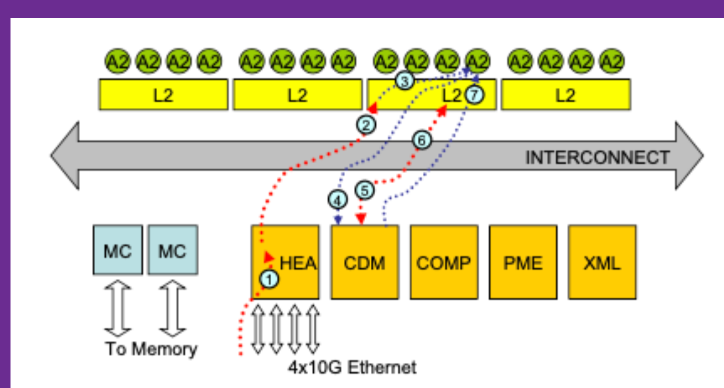
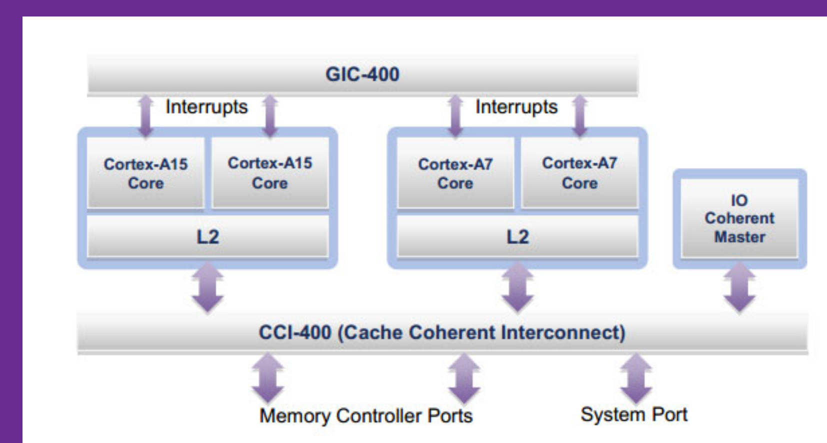


Figure 1: PowerEN Chip Overview

ARM big.LITTLE [6]



Alongside FPGAs, VLIW, and a range of multi-threaded architectures.

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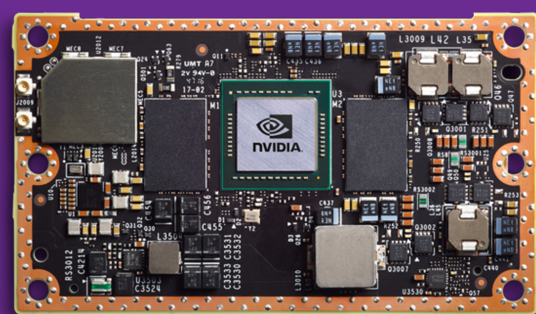
Innovation circa 2021

NVIDIA Jetson [8]



HiSilicon Kirin [12]

Xilinx Ultra96 [10]

Intel Xe GPUs [9]

Heterogeneous technology has moved down into the mobile space.

What is the performance story?

Real-world Performance

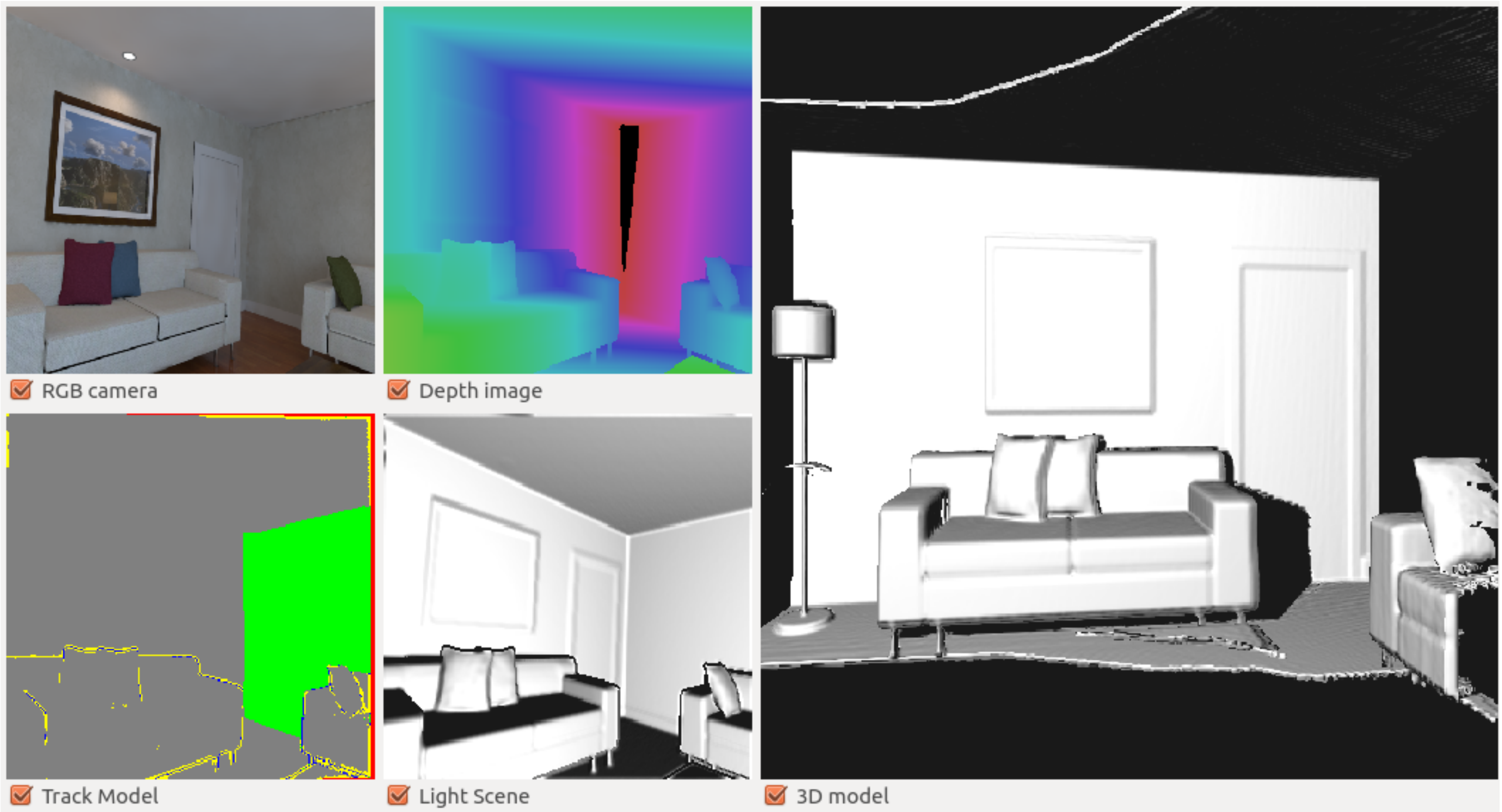
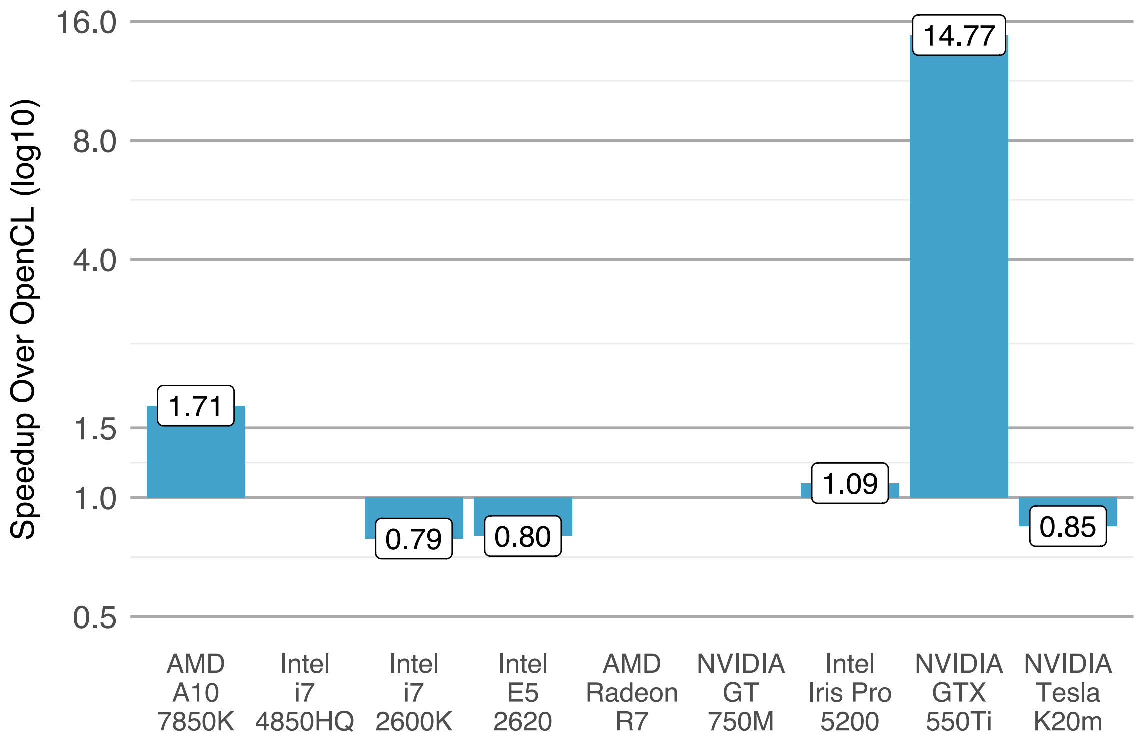
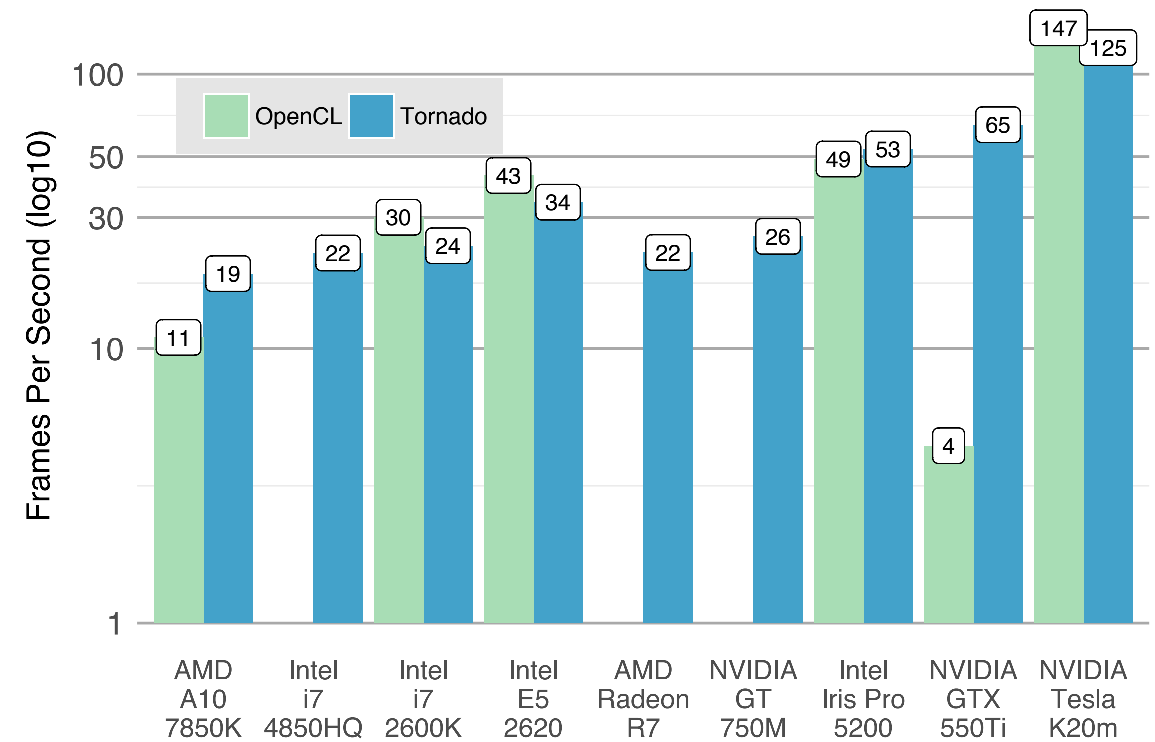
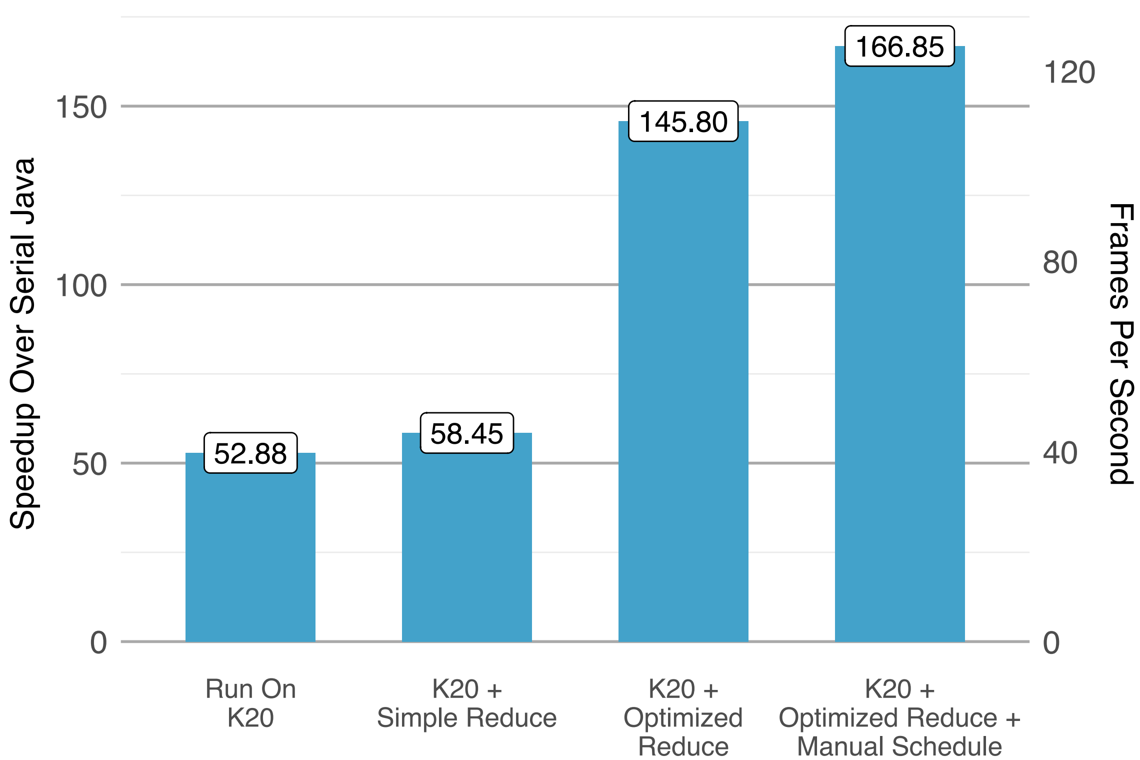


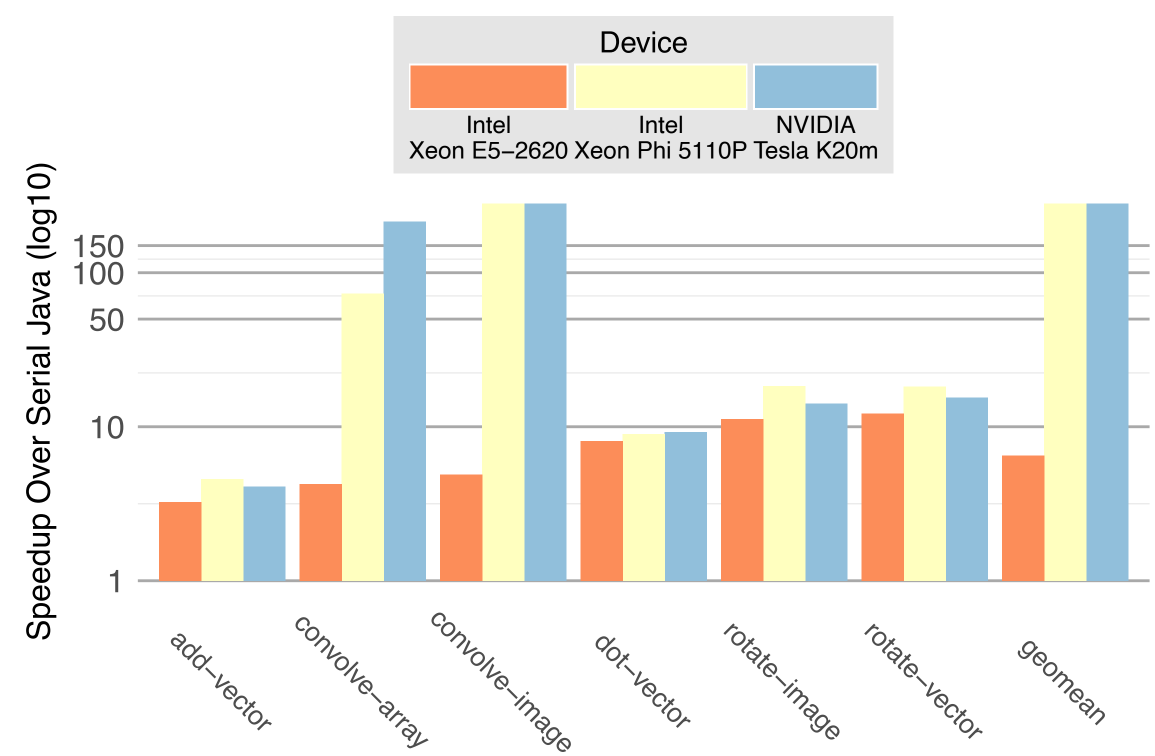
Image from SLAMbench [4]

Performance









Results taken from [1]

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Summary

- There is lots of cool kit out there that is inaccessible!
- With Tornado we tried to look at the problem differently — from an ergonomic viewpoint; not performance.
- Able to show that there is a route to programming this hardware in more virtual-machine based languages that:
    - Retains their productivity features…
    - …without degrading performance (too much).
    - (Tried to) open hardware accelerators up to a new demographic.

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Questions?

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