Programming Languages and Analyses for HPC

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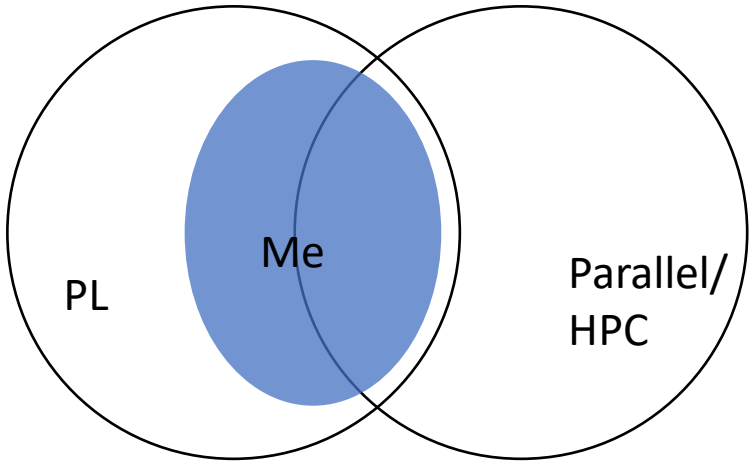
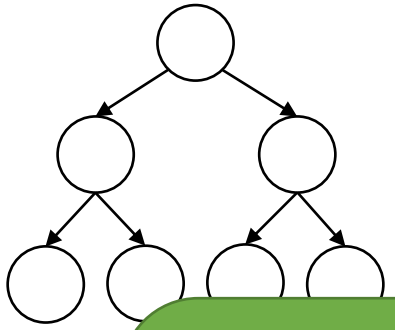
Argonne-Illinois Tech Research Seminar

Mar. 23, 2022

Short Bio

- PhD 2018, CMU
  - Thesis: Responsive Parallel Computation
- Postdoc, CMU, 2018-2020
  - Static analysis for research usage, especially in CUDA
- Joined Illinois Tech CS in 2020





Cilk, Go, Parallel ML, Parallel Haskell, …

Theorem: $T(P) \leq \frac{W}{P} + S$

So why don't people use the abstractions?

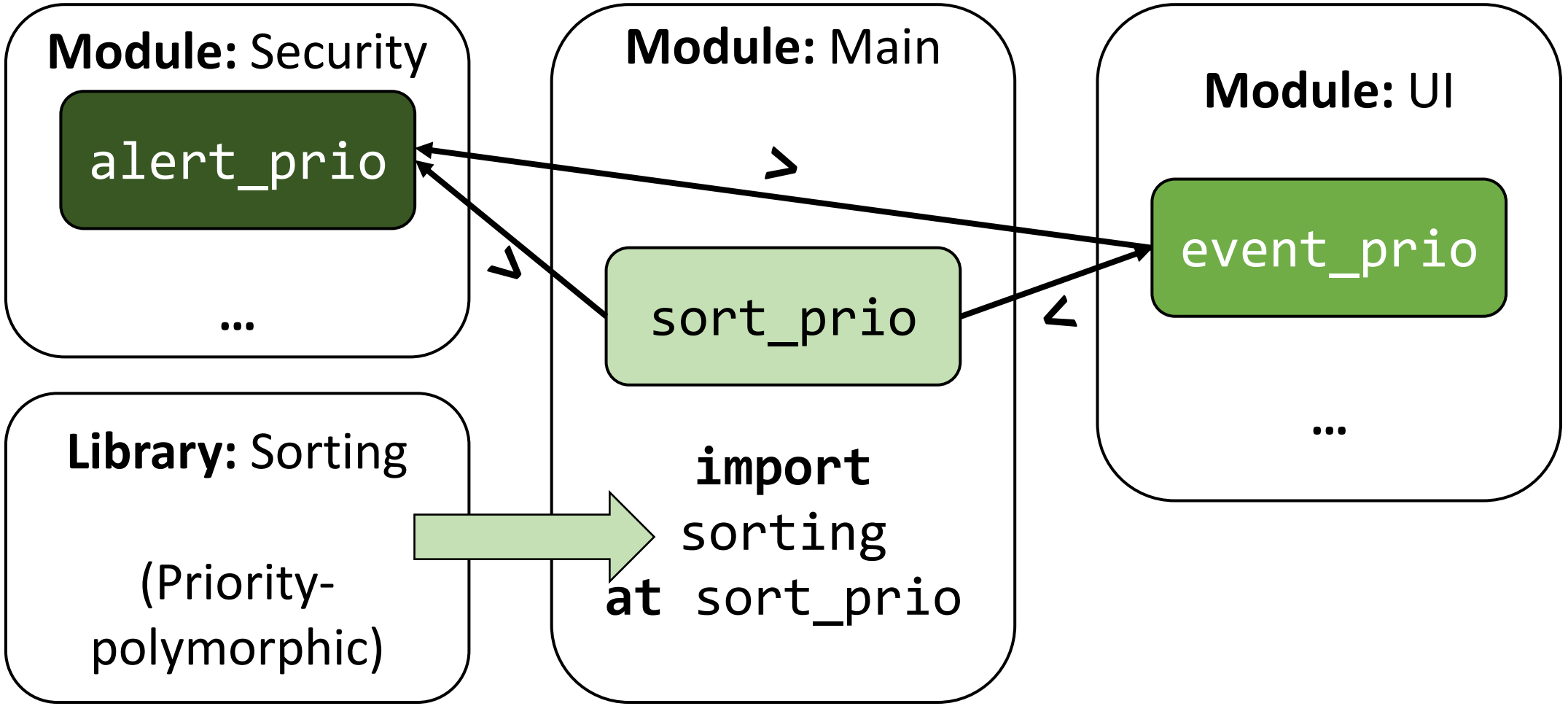
(Short answer: user interaction)

POSIX threads

My PhD thesis

- Extend implicitly parallel languages with priorities for responsiveness

Partial order of priorities provides an intuitive, **modular** abstraction



We track priorities through code in **types**

```
order low < high

cmd[high]
{
  t <- spawn[high] { … };
  …
  sync(t)
}
```

- This thread is high-priority
- Spawn a high-priority thread
- Sync on it

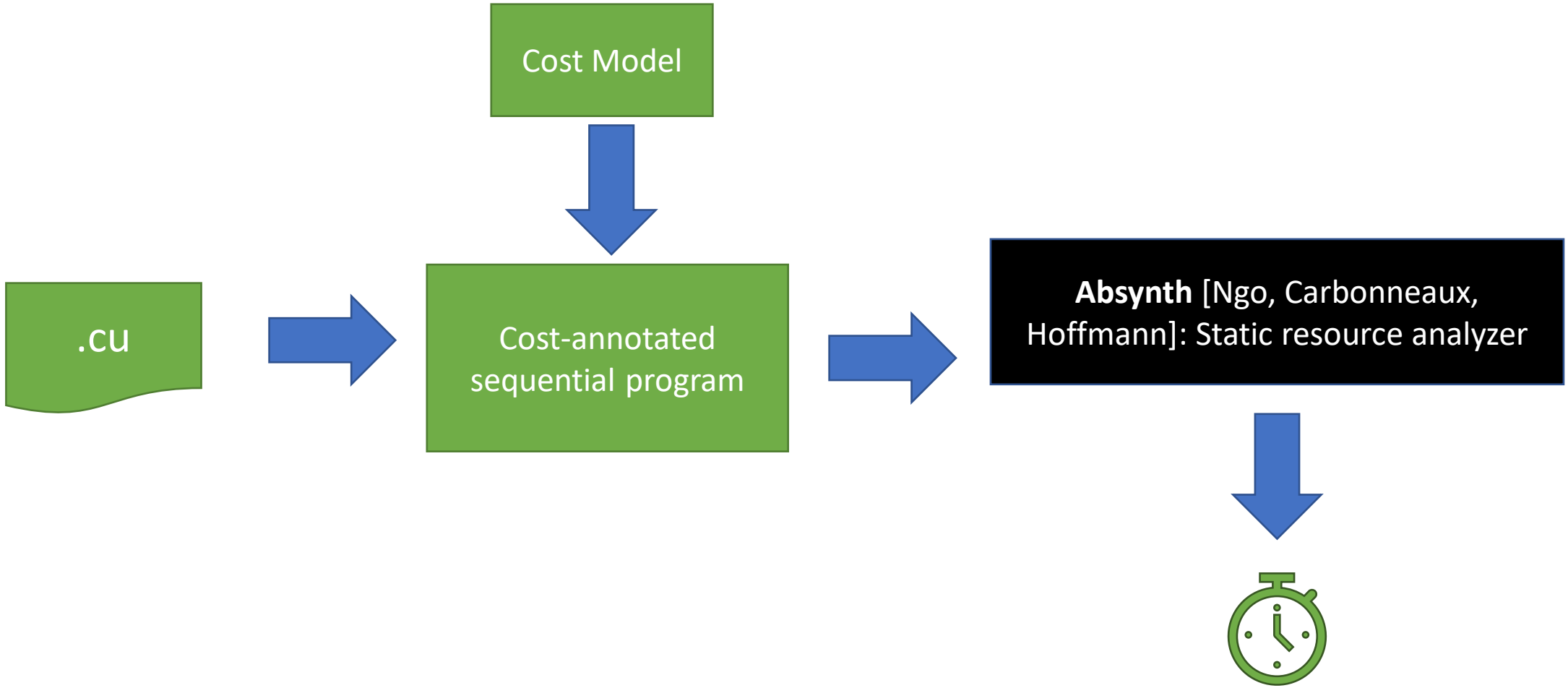
```
constraint violated at example.prm:5.1-5.8 :  high  <=  low
Type error: constraint violated
```

CUDA

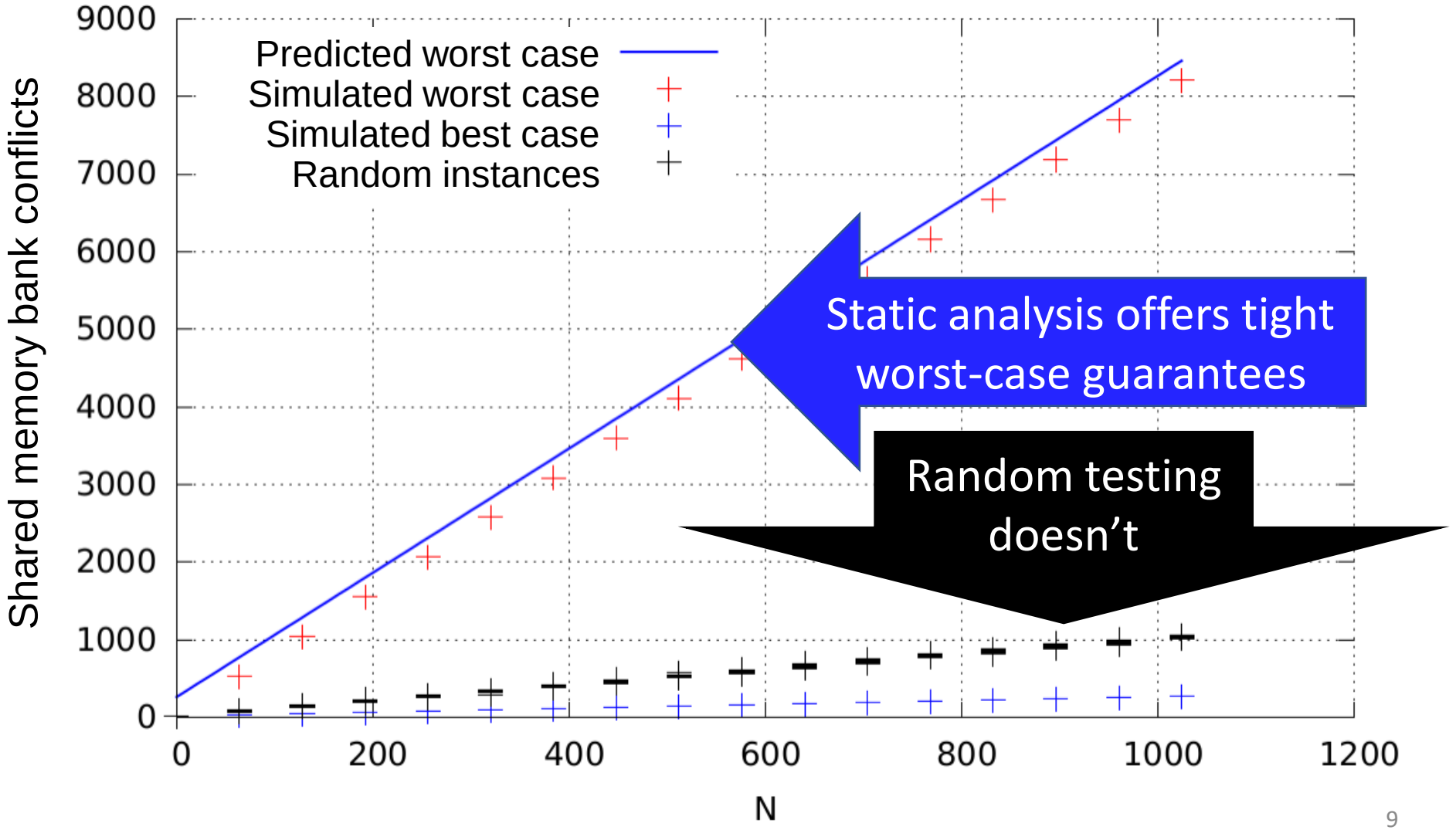
- The promise: write C programs, run them on GPUs!

- The reality: complicated execution model, unexpected performance bottlenecks:
  - Warp divergences
  - Uncoalesced memory accesses
  - Bank conflicts

End-to-end static analysis for CUDA resource usage



Static timing analysis is important for critical applications



CUDA: Current Work

- Automatically optimize programs
- Analyze and predict thread-level parallelism

Very new project: dependent array descriptors

MPI_Send

int **A

(Part of joint work with Zhiling Lan, Valerie Taylor, Mike Papka, Romit Maulik and Xingfu Wu)

```
for (i = 0; i < N; i++) {
  for (j = 0; j < M; j++) {
    … A[i][j] …
  }
}
```

Very new project: dependent array descriptors

int **A

```
for (i = i0; i < i1; i++) {
  for (j = j0; j < j1; j++) {
    … A[i][j] …
  }
}
```

Very new project: dependent array descriptors

MPI_Send

int **A2

```
for (i = i0; i < i1; i++) {
  for (j = j0; j < j1; j++) {
    A2[i – i0][j – j0] = A[i][j]
  }
}
```

```
for (i = 0; i < i1 – i0; i++) {
  for (j = 0; j < j1 – j0; j++) {
    … A2[i][j] …
  }
}
```

Very new project: dependent array descriptors

MPI_Send

int **A

Goal: **automatically** generate code to send minimal amount of data

```
for (i = 0; i < N; i++) {
  for (j = 0; j < M; j++) {
    if (A[i][j] != 0) {
      (A[i][j] % 2 == 0)
      f(A[i][j])
      …
    }
}
```

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