
SIGGRAPH2015
Xroads of Discovery

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The 42nd International Conference and Exhibition
on Computer Graphics and Interactive Techniques

Presto Execution System

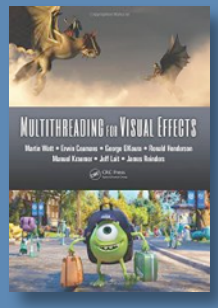
An Asynchronous Computation Engine for Animation

George ElKoura
Pixar

More Info

@multithreadvfx

www.multithreadingandvfx.org



“Multithreading for Visual Effects”

Team

Engineering

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Thanks

Steve May Guido Quaroni Adam Woodbury
Dirk Van Gelder Alicia Mooty

Pixar Software R&D

Overview

- What is Presto?
- Execution system architecture
- Multithreading strategies
- Switching a large code base to TBB

Presto Execution

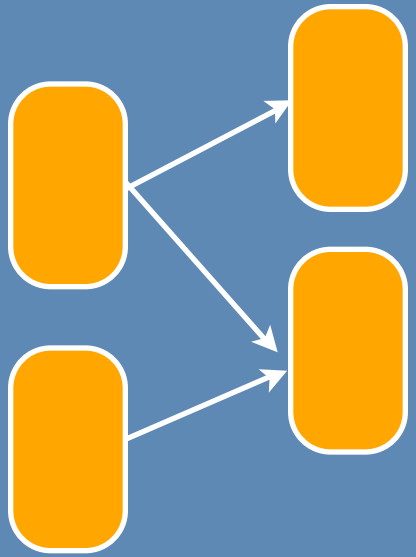
- The Presto Execution System:
  - A general purpose execution engine
  - Commonly used for posing points
  - Must be as fast as possible

Phases of Execution

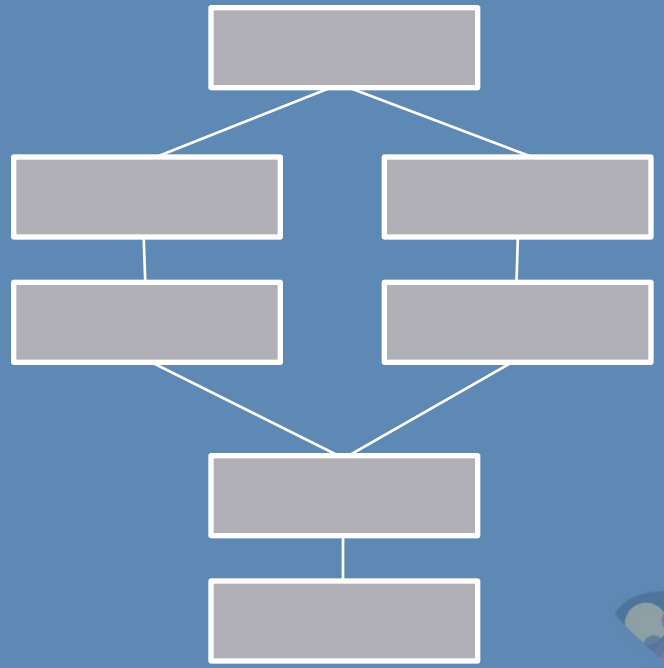
- Execution is broken up into three phases:
  - Compilation
  - Scheduling
  - Evaluation

Compilation

User-Authored Scene Objects



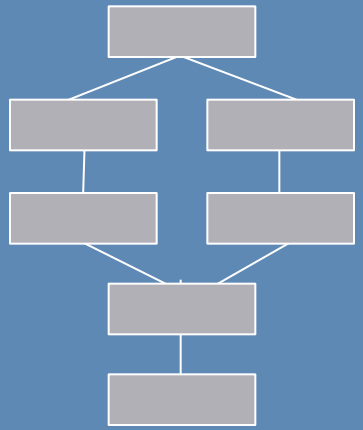
Compilation



Compiled Data Flow Network

Scheduling

Compiled Network



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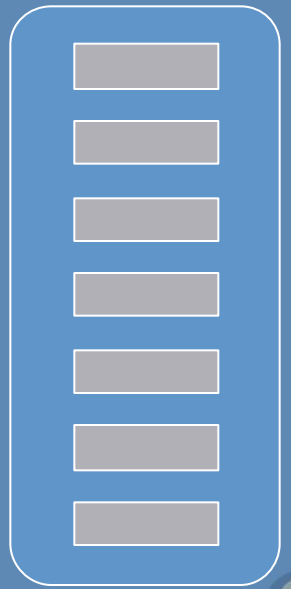
Client Request

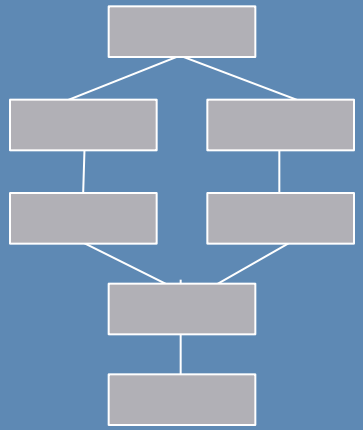
Request
Body points
Body transform
Head points
Head transform

Scheduling



Evaluation

Compiled Network



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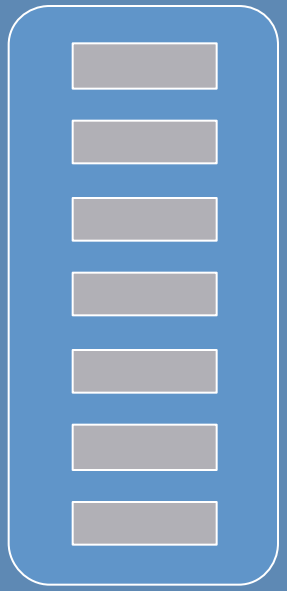
Schedule



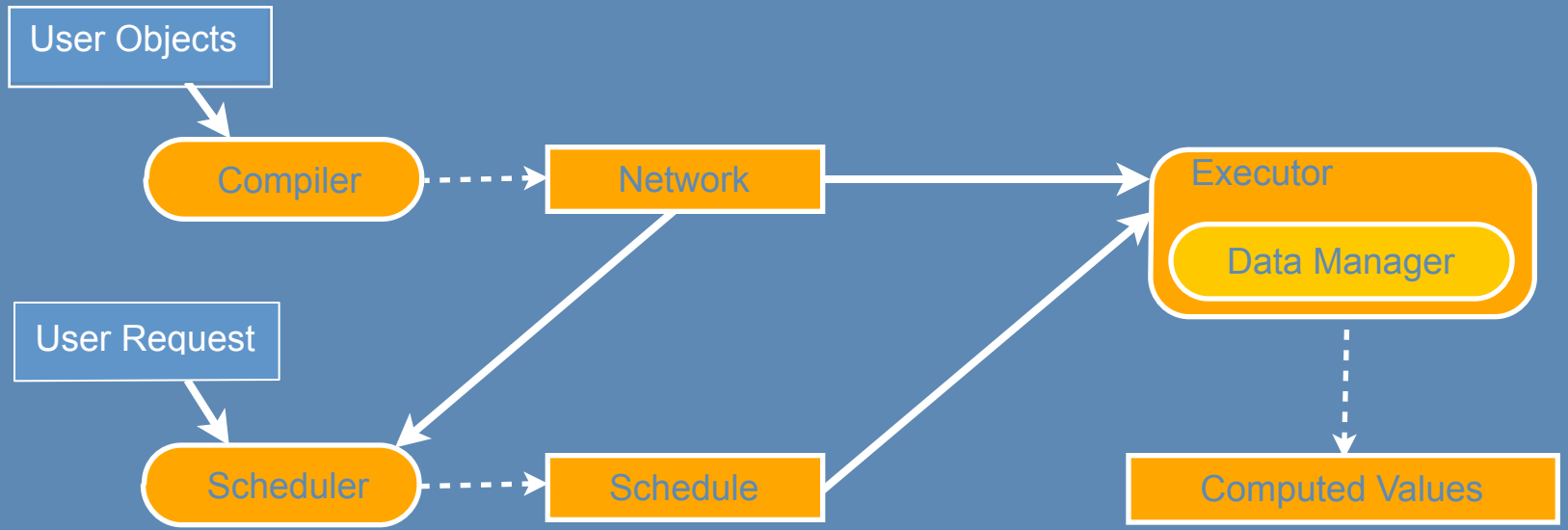
Evaluation

Results

Computed Values

(1.4, 0.0, 2.4)
(1.4, -0.784, 2.4)
(0.784, -1.4, 2.4)
(0.0, -1.4, 2.4)
(1.3375, 0.0, 2.53125)
(1.3375, -0.749, 2.53125)
(0.749, -1.3375, 2.53125)
(1.4375, 0.0, 2.53125)
(1.4375, -0.805, 2.53125)
(0.805, -1.4375, 2.53125)
(0.0, -1.4375, 2.53125)
(1.5, 0.0, 2.4)
...

Exec Engine Architecture



User Extensions

- Plugin support
- Need painless multithreading
- Provide safeguards to help

Execution Callbacks

```
static void
MyCallback(const Context &context)
{
    ...
}
```

Execution Callbacks

- Iterators are provided for vectorized data access...
- which allows for easier experimentation with multithreading strategies.

User Gotchas

- Avoid global and static variables
- Be careful about singletons
- Using a non-thread-safe 3rd party library requires users to do their own locking
- ... and, of course, Python

Python in Execution

- Global Interpreter Lock (GIL)
- Only one thread at a time
- Do heavy lifting in C++
- Look out for GIL deadlocks

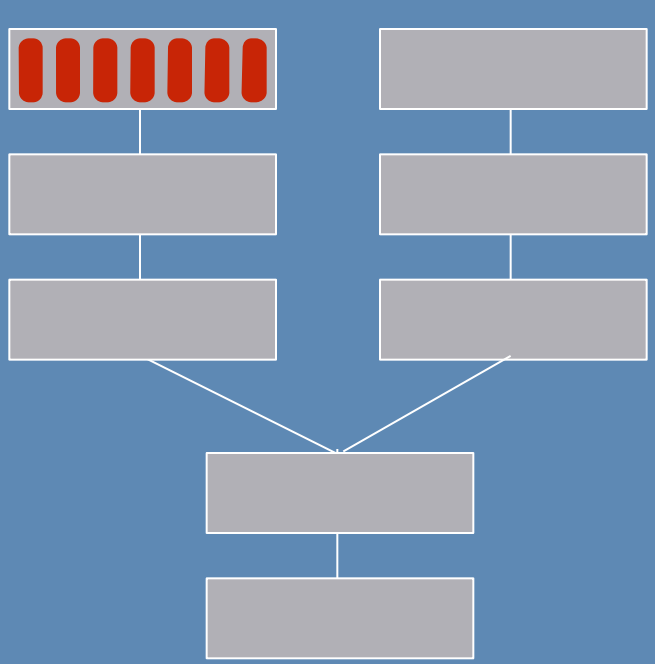
Flexibility to Experiment

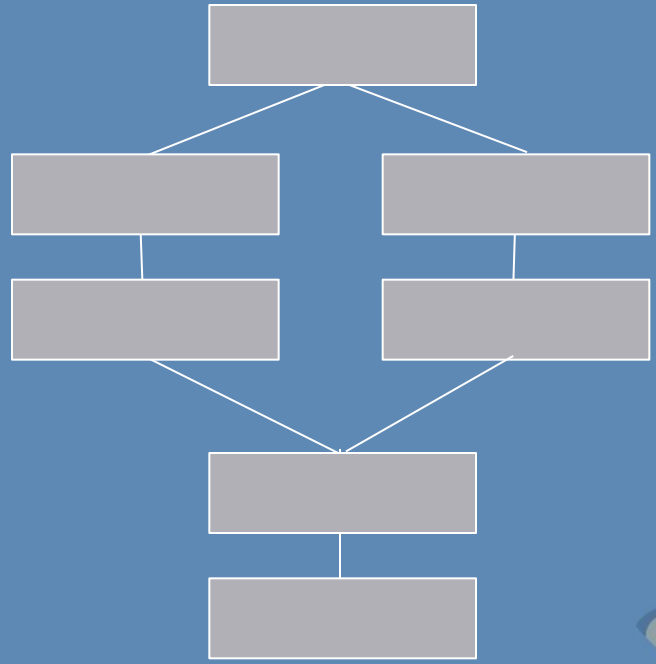
- Modular, adaptable design, e.g.:
  - Hardware changes: rewrite executor, possibly scheduler
  - User representation changes: rewrite compilation
- Allows for easy experimentation with different algorithms

Multithreading

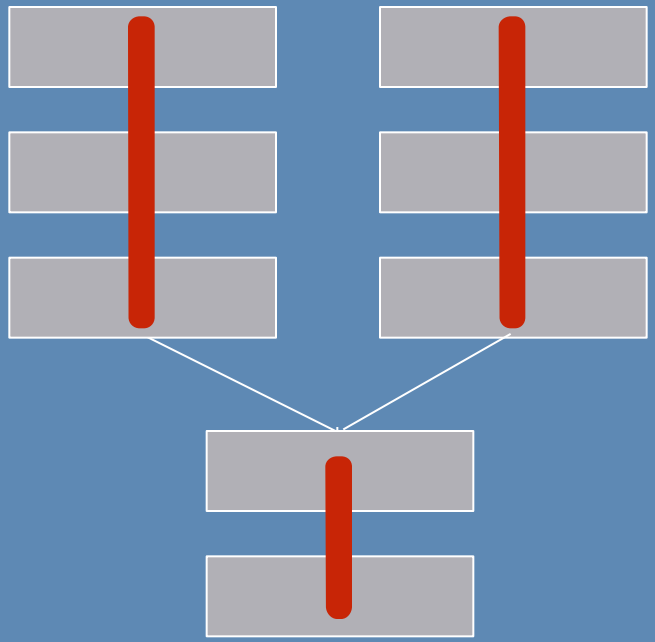
- Computed data not in the network
- Stateless computations
- Modular schedulers and executors

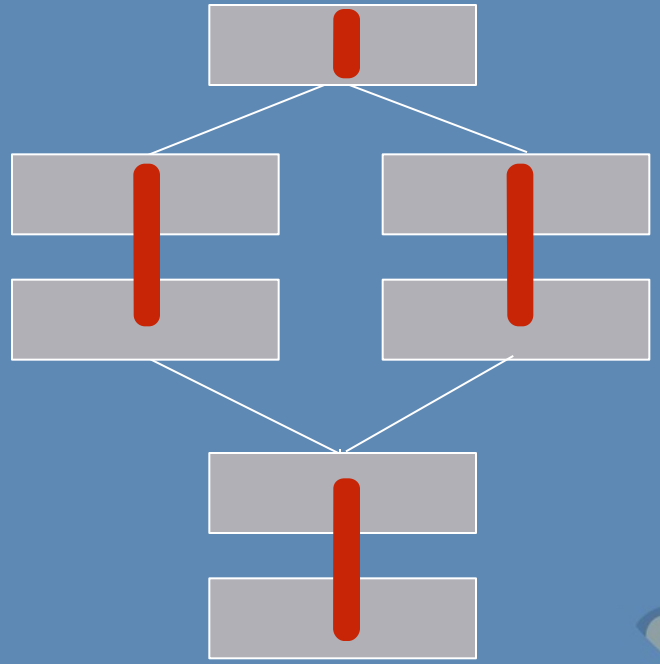
Per Node



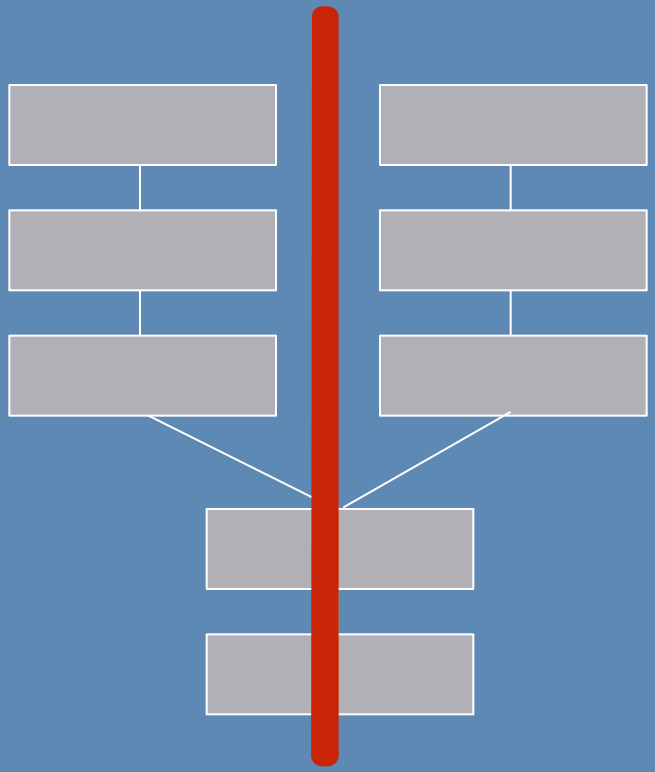


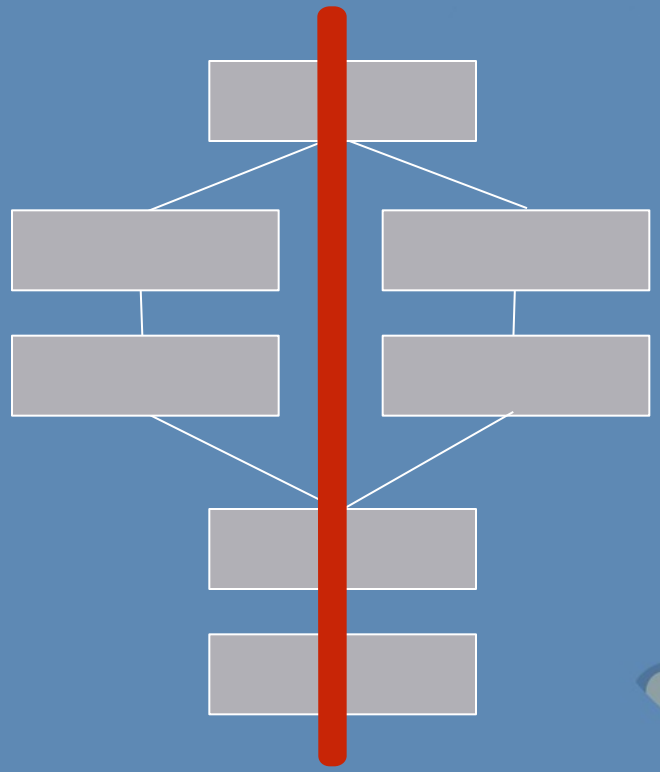
Per Branch



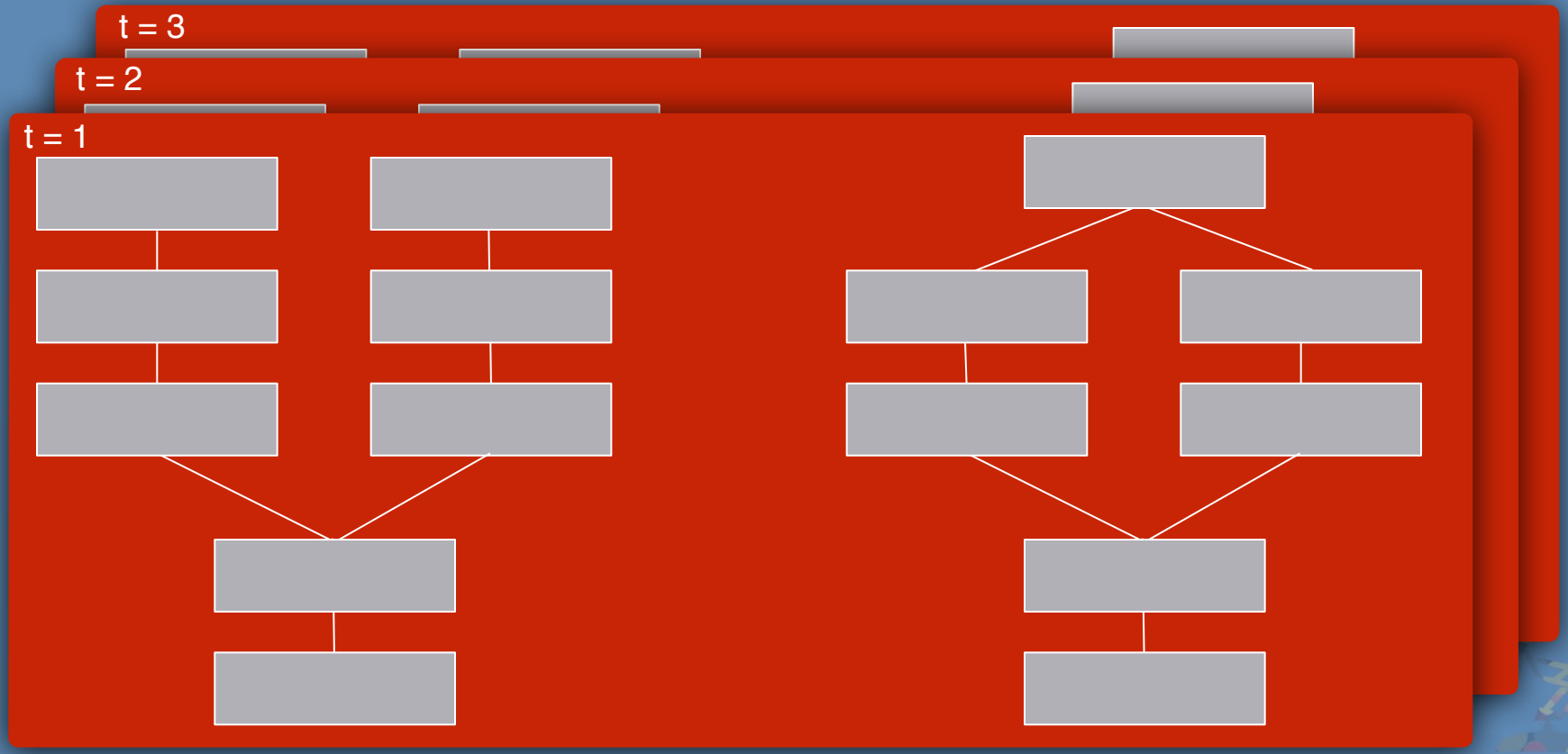


Per Model





Per Frame



Background Execution

- Evaluates entire frames at different times in parallel and in the background
- Fills in a computed value cache

Interruption

- If values change, we must interrupt, but…
- We can’t block to wait for it to interrupt.

Interruption

- Avoid `pthread_cancel` and `pthread_kill`
- Instead, we use a cooperative scheme...
- and throw away results.

TBB

Switching to TBB

- We had our own threading toolkit
- Built on for a decade or two
- Lacked modern features
- Wanted to switch to TBB

libWork

1. Create abstraction
2. Convert clients
   - Don’t disrupt shipping software
3. Implement TBB backend
4. Flip the switch

libWork Abstractions

- Parallel For
- Fixed Dispatcher
- Dynamic Dispatcher
- Background Job

Switching to TBB is Easy!

```
#define WORK_USE_TBB ~~0~~ 1
```

Unexpected Deadlocks

```
void F()
{
    // do something ...
    A();
    // do more things ...
}
```

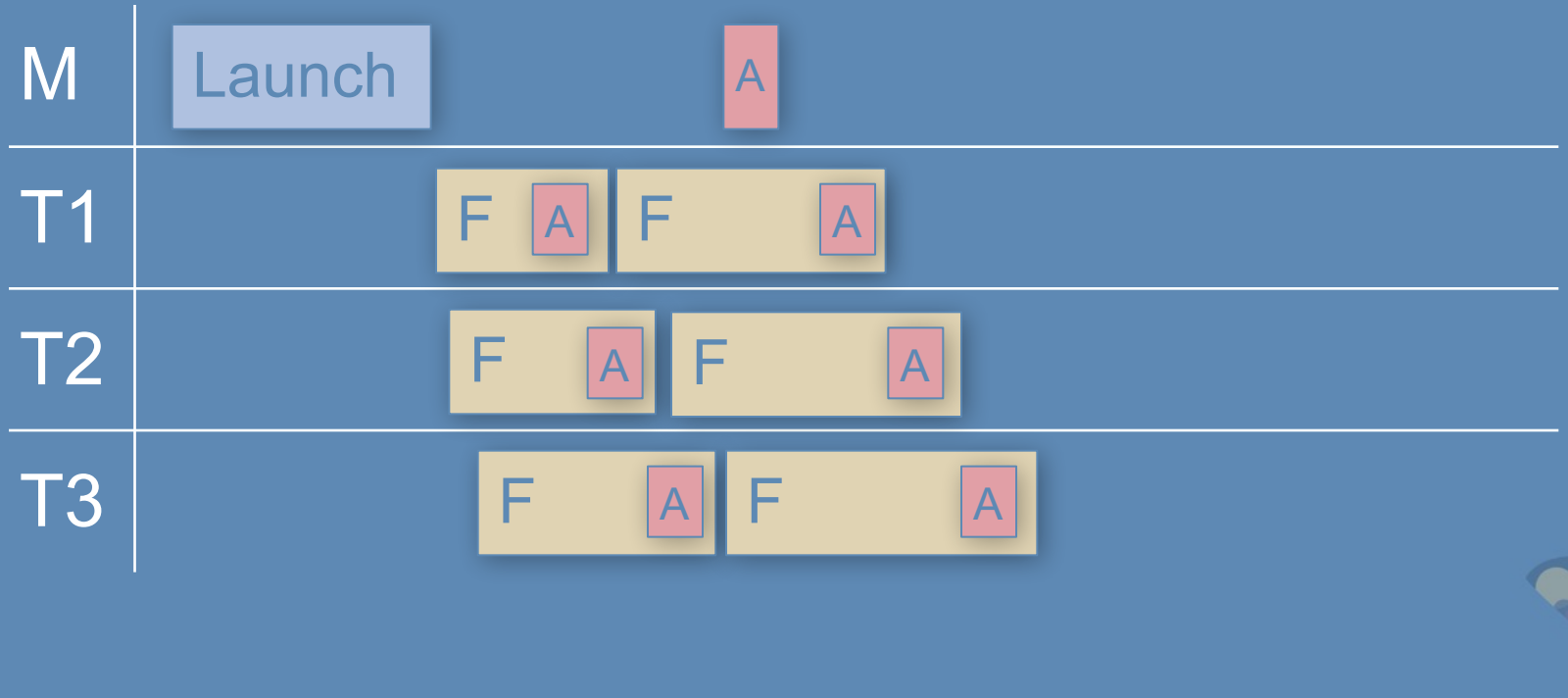
Unexpected Deadlocks

```
A () {
    Lock a;
    if (cache.Lookup())
        return hit;
    parallel_for([]{ fill in cache })
    return hit;
}
```

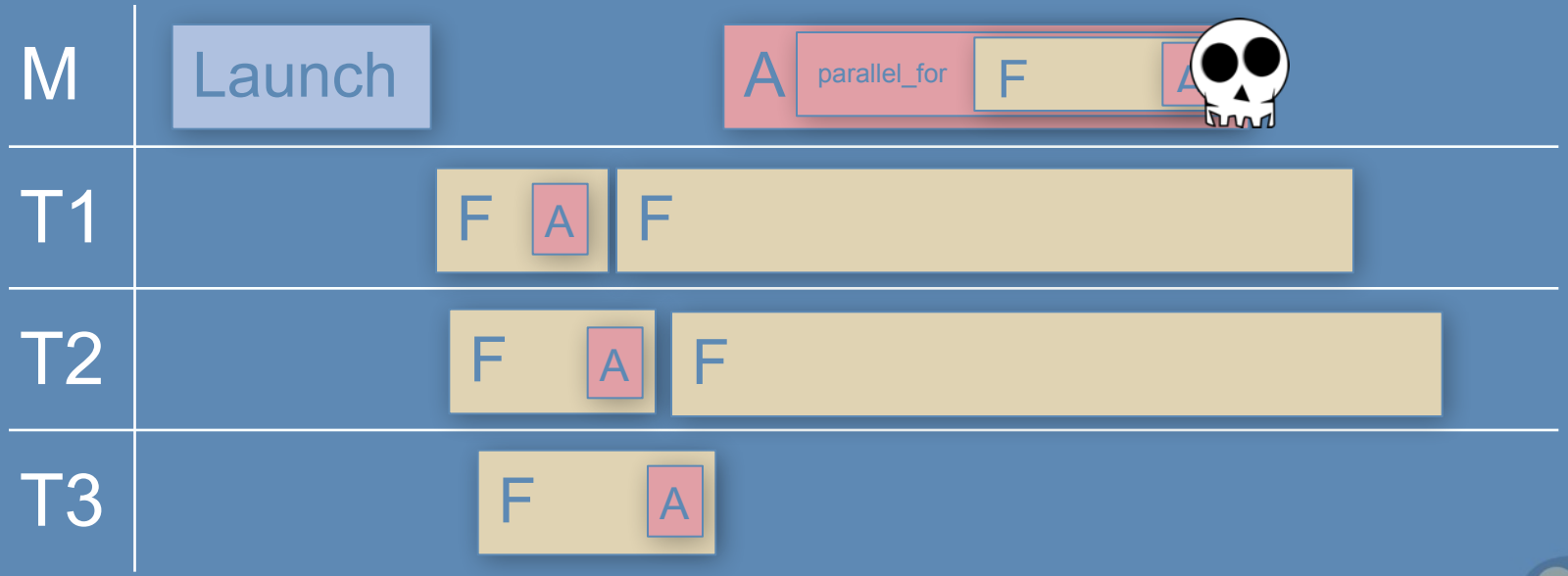
Unexpected Deadlocks

```
int main() {
    …
    Spawn_many_tasks_running_F();
    A();
    Wait_for_Fs();
    …
}
```

Without Work Stealing



With Work Stealing



Unexpected Deadlocks

```
A () {
    Lock a;
    if (cache.Lookup())
        return hit;
    parallel_for([]{ fill in cache })
    return hit;
}
```

not smart!

Thread Throttling

- Had strict control
- TBB hungry
- tbb::task_scheduler_init()

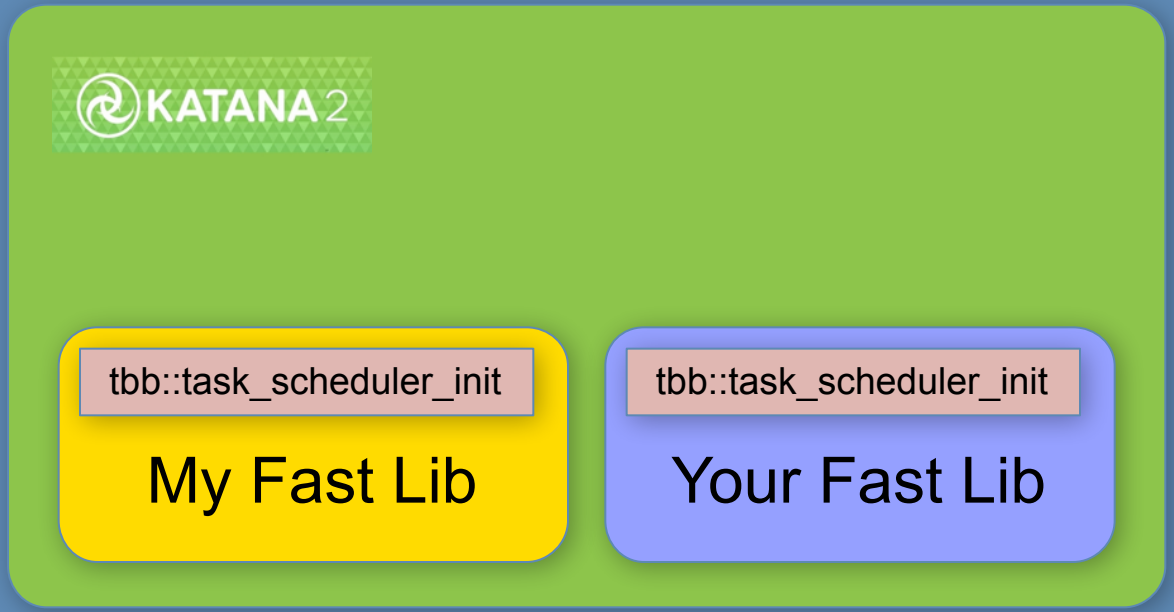
tbb::task_scheduler_init

- Hard in embedded libs
- Stack object, must go first
- Who goes first?

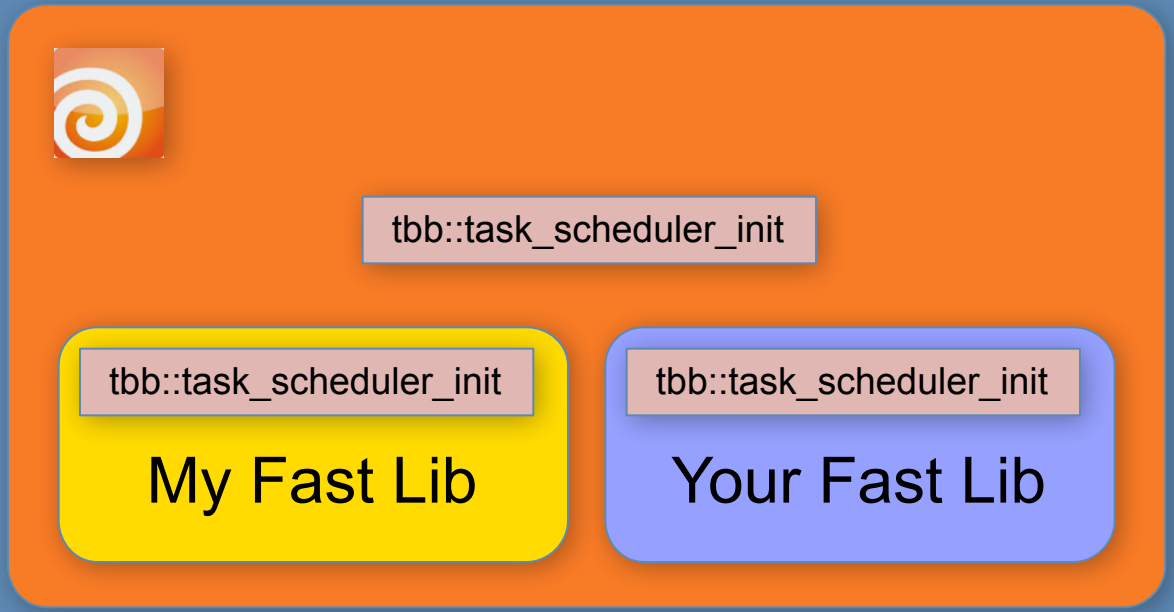
In Practice

In Practice

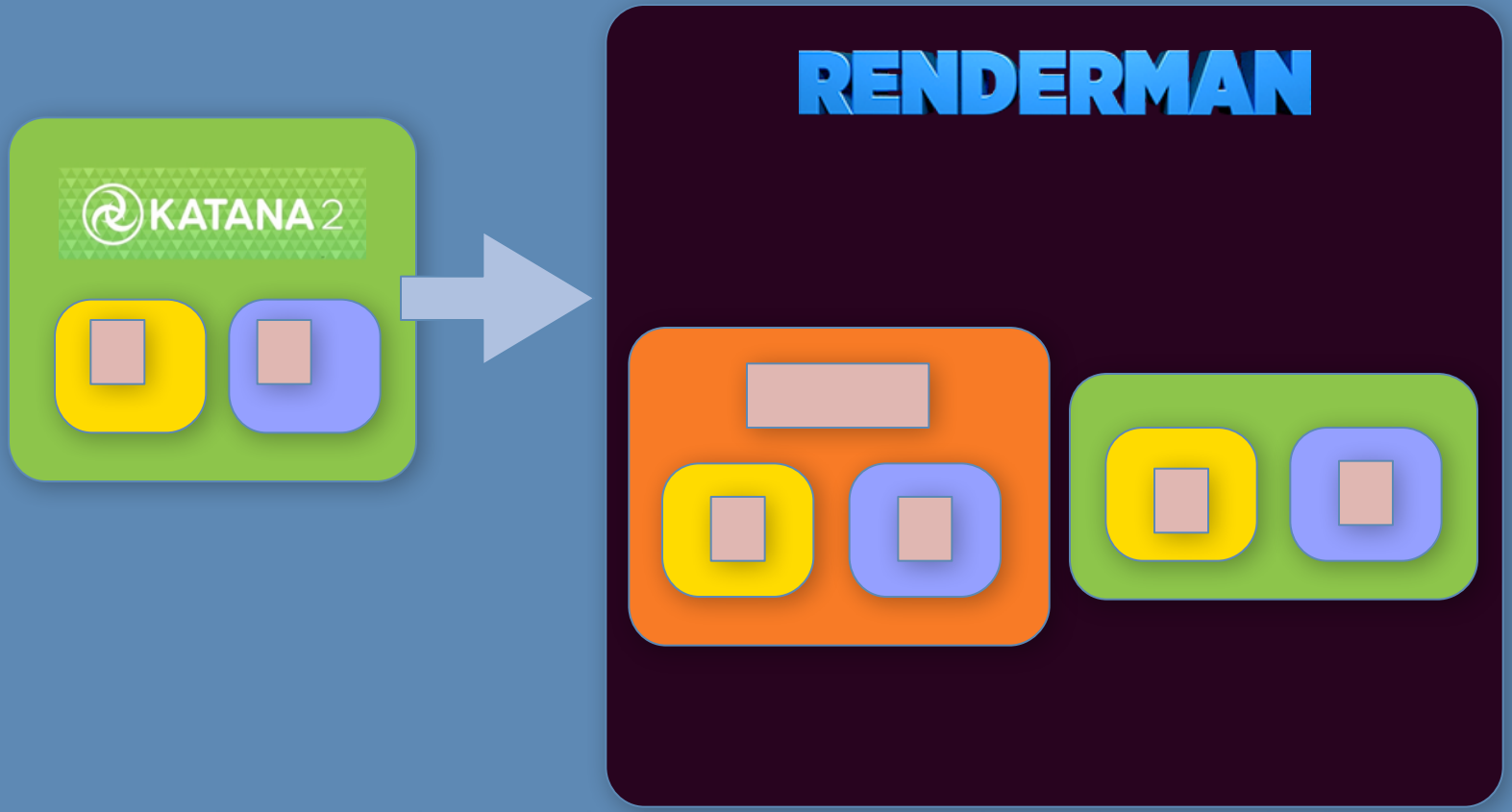
In Practice


KATANA 2
tbb::task_scheduler_init
My Fast Lib
tbb::task_scheduler_init
Your Fast Lib

In Practice


tbb::task_scheduler_init
tbb::task_scheduler_init
My Fast Lib
tbb::task_scheduler_init
Your Fast Lib

All on one machine...



What we’re doing

- Don’t oversubscribe the farm
- Centralize decision making
- So far okay, not great

Recap

- Separate your data from your algorithm
- Build modular systems
- TBB is great
- Think in tasks, not threads
- Careful with resource management

THANKS!

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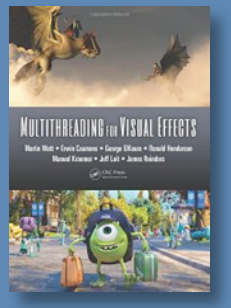

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