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GPU Task-Parallelism: Primitives and Applications

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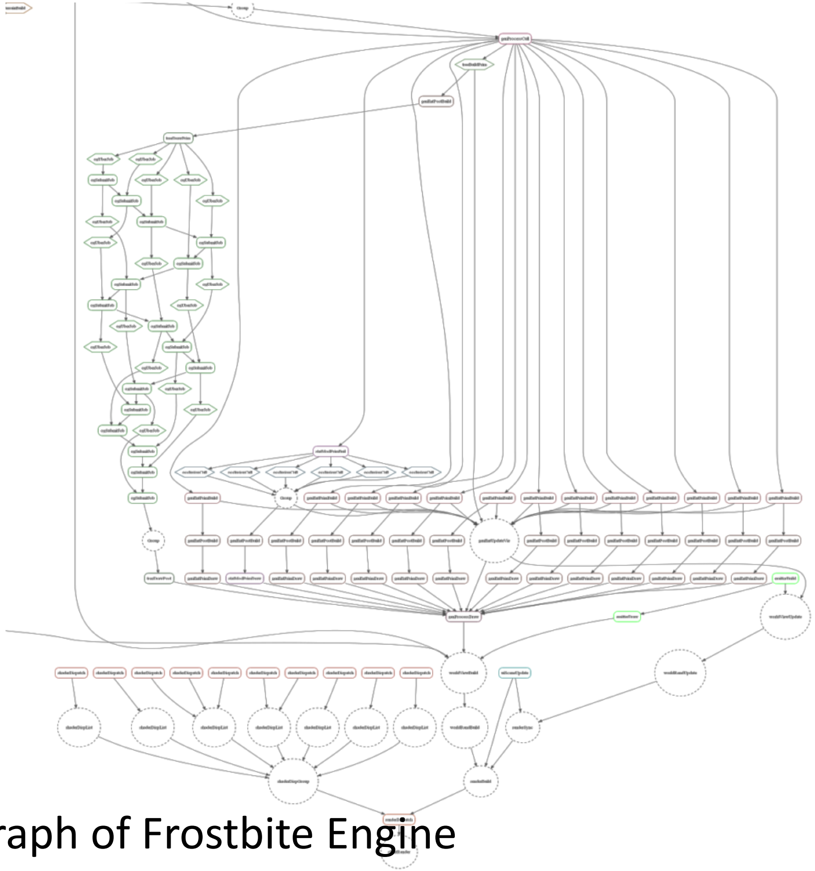
This talk

- Will introduce task-parallelism on GPUs
  - What is it?
  - Why is it important?
  - How do we do it?
- We will discuss
  - Primitives
  - Applications

What is Task Parallelism

- Task: A logically related set of instructions executed in a single context.
- Task-parallelism: Tasks processed concurrently
  - A scheduling component figures out how to distribute tasks to available computing resources
- Examples: Cilk, Intel TBB, OpenMP



Task graph of Frostbite Engine

GPU task parallelism: Why NOT?

- GPUs are **data-parallel**
  - GPU hardware built around data-parallel processing
  - CUDA is a data-parallel abstraction
- Task-based workloads are ignored (so far)

Task Parallelism on GPUs

GPU task parallelism: Why?

- Extends the scope of GPU programming
- Many task-parallel problems still exhibit ample amount of parallelism
- This lecture: programming the GPU as a task-parallel device
- Split into two parts: **Primitives** and **Applications**

You after this lecture

Primitives: Goals

● Task

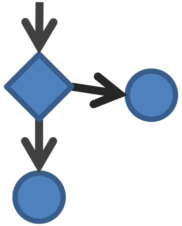
🟧 Data

▬ SM

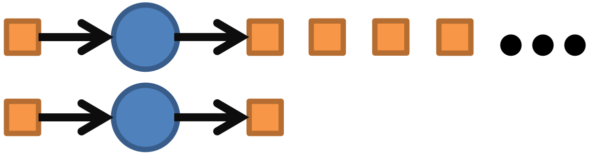
┆ Barrier

Build a task-parallel system that can:

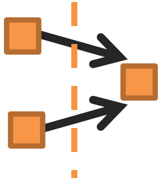
- Handle divergent workflows



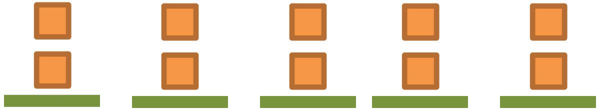
- Handle irregular parallelism



- Respect dependencies between tasks



- Load balance all of this



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● Task

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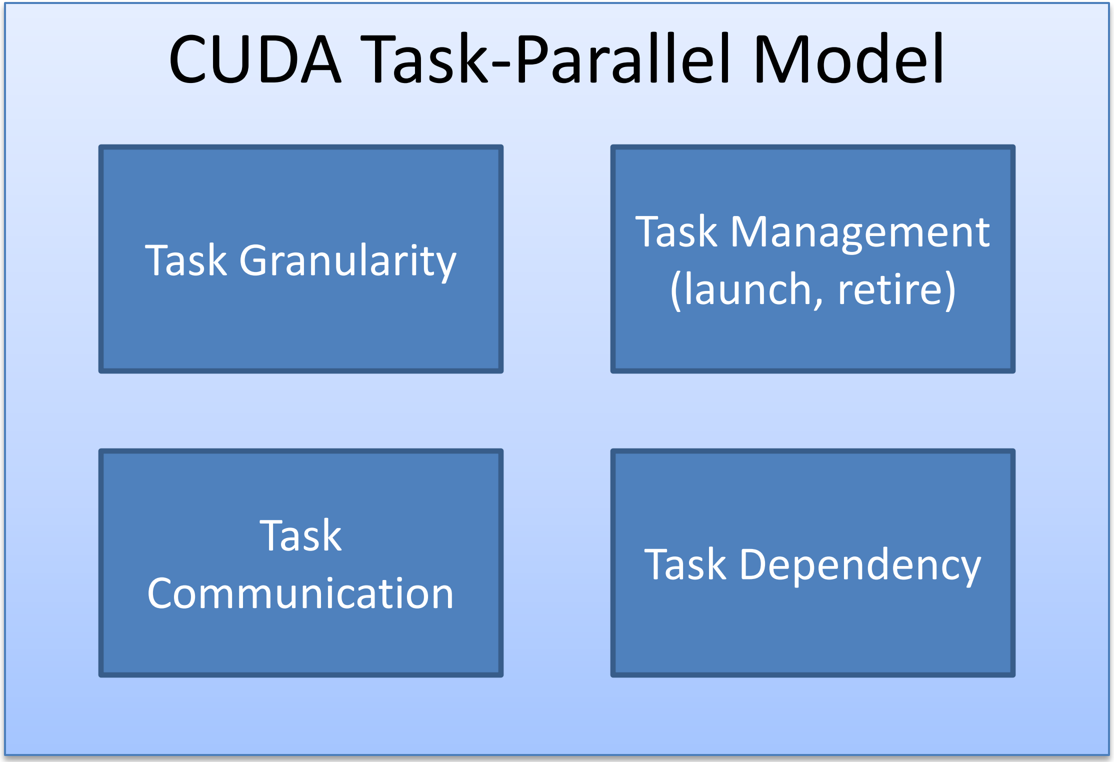
¦ Barrier

Primitives: Outline



CUDA Task-Parallel Model

Task Granularity

Task Management (launch, retire)

Task Communication

Task Dependency

Task Granularity

What is the right parallel granularity to handle tasks?

- One task per thread? Okay
- One task per warp? Better

Become SIMD-aware! Think of warps as MIMD threads with a 32-wide vector lane.

Task Management

How do we keep processing tasks until there are none left?

- Persistent thread programming model.
- `while(stillWorkToDo){// run task }`
- Decouples launch bounds from amount of work.

Beware of deadlocks!

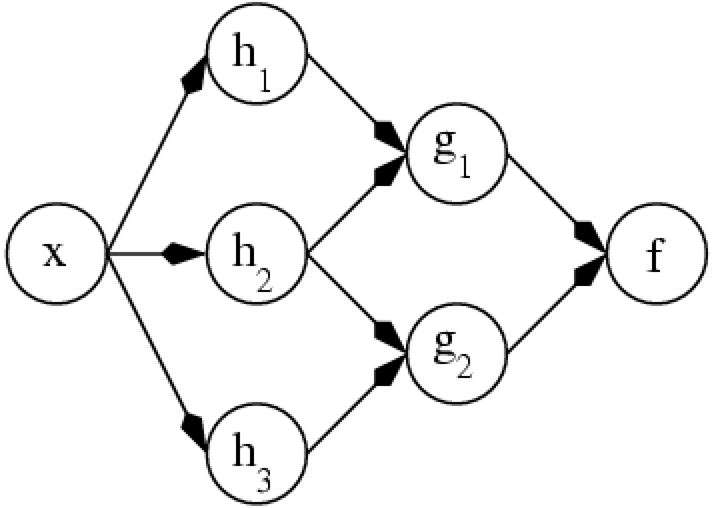
Task Communication

How do we distribute tasks evenly between SMs?

- Distributed queues with a work donation routine (see GTC 2010)
- A single block queue: atomics are now fast enough and this is simple enough

Task Dependency

- What if tasks had dependencies?
- How do we augment our current system to respect dependencies?



Dependency Resolution

- All tasks put on our queue are executed without notion of dependencies.
- Dependencies affect which tasks can be placed in the work queue.
- Maintain a task dependency map that each warp must check before queuing additional work.

Dependency Resolution

```
while(Q is not empty)
{
  task t = Q.pop()
  Process (t)
  Neighbors tnset = dependencyMap(t)
  For each tn in tnset
  tn.dependencyCount--;
  if(tn.dependencyCount == 0) Q.push(tn);
}
```

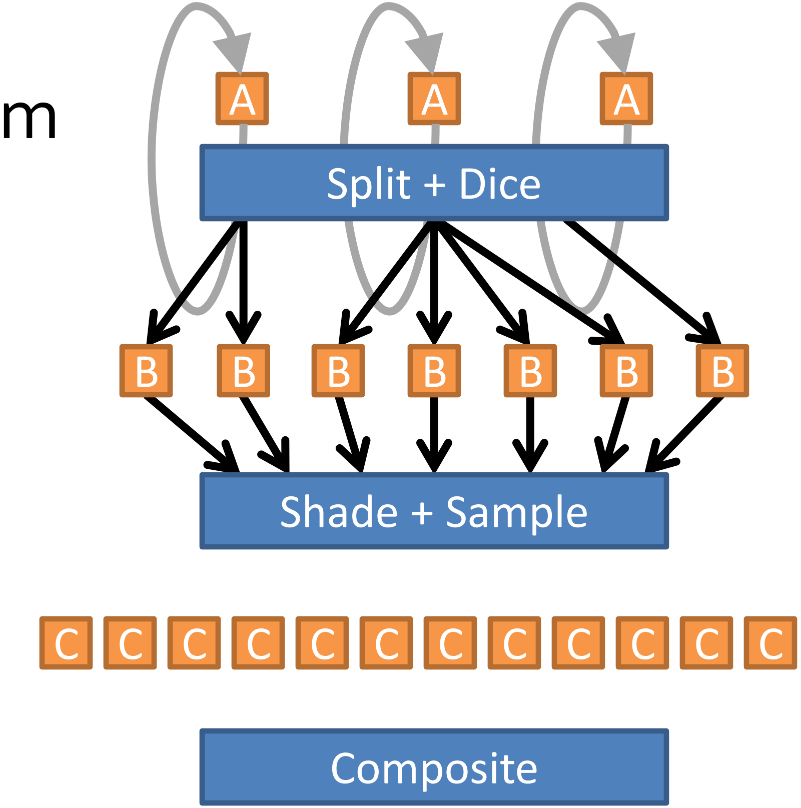
Applications

- A variety of scenarios demand task-parallelism
- We will discuss three
  - Reyes Rendering
  - Deferred Lighting
  - Video Encoding
- We only use primitives that are necessary

Application: Reyes

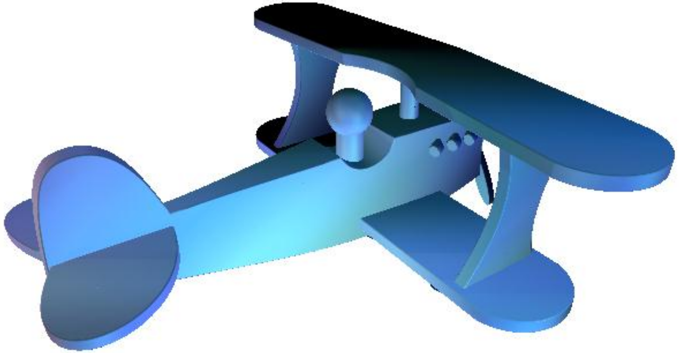
Application: Reyes

- Why we need task-parallelism
  - Irregular parallelism
  - Dynamic communication
- What primitives do we need
  - Persistent Threads
  - Dynamic Task-Queues



Application: Deferred Lighting

- Different lights affect different parts of the screen
- So we subdivide tiles with too many lights
- Original idea by Lauritzen and at DICE



Application: Deferred Lighting

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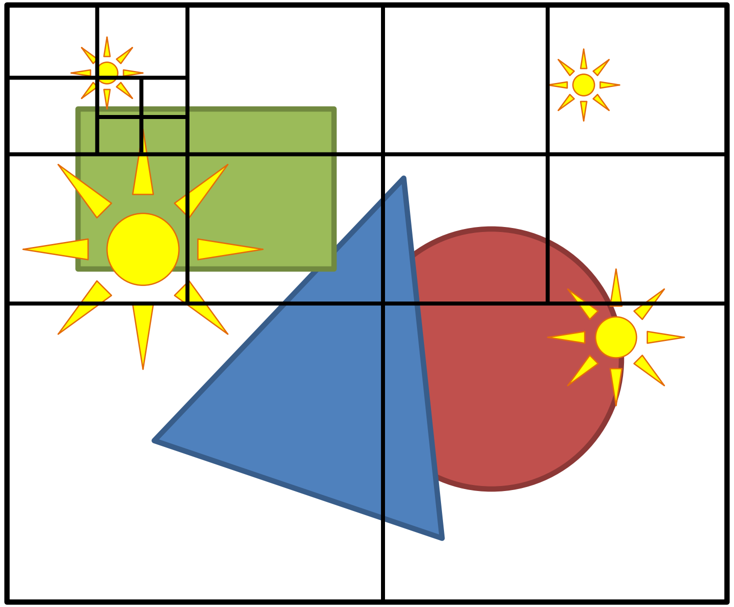
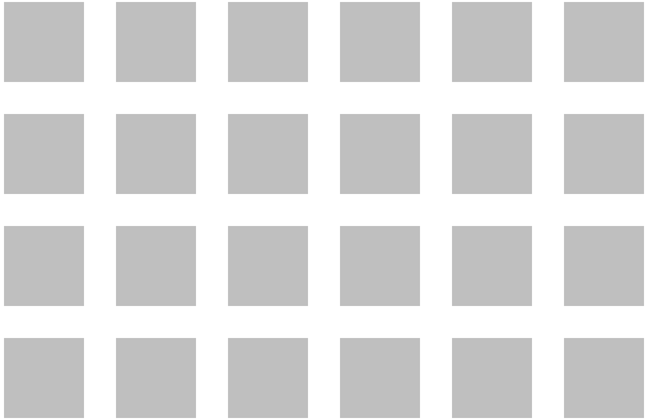


Application: Video Encoding

- H.264 Encoding using GPUs
  - Past work on inter-prediction
  - We consider intra-prediction
- We show both using task-parallelism
- Consider 16x16 macroblocks
  - Each forms a task

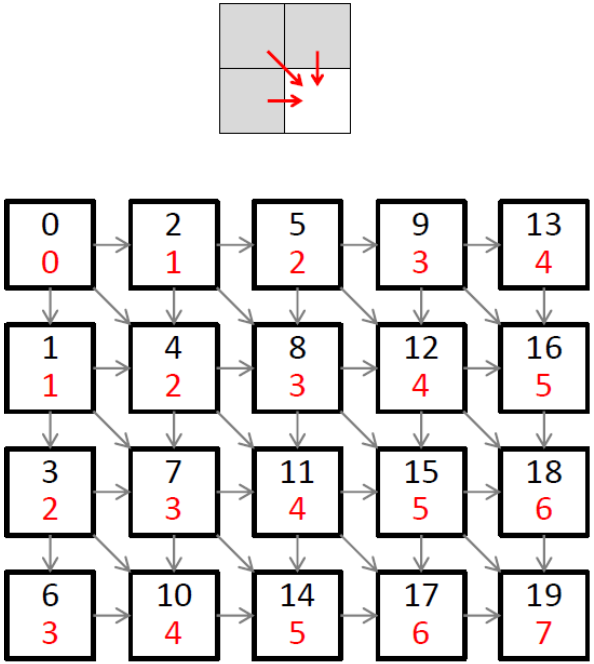
Application: Video Encoding

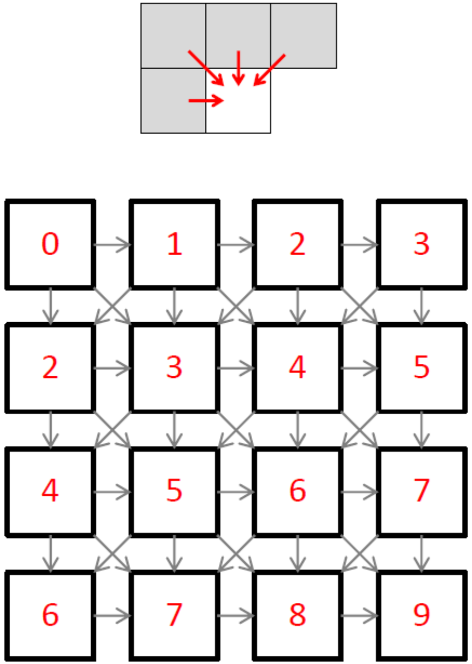
- Why we need task-parallelism
  - Task dependencies
  - Dynamic communication
- What primitives do we need
  - Dependency resolution



Intra Prediction

- Intra prediction has dependencies between tasks





Summary

- Task parallelism is important
  - Many application scenarios
- Several fundamental primitives
  - Braided task-granularity
  - Persistent threads
  - Dynamic queuing
  - Dependency resolution

Thanks!

For papers on these works, please visit

http://csiflabs.cs.ucdavis.edu/~stzeng/

Backup slides

Optimization?

- What if:
  - The number of tasks is fixed, but cannot be executed because of dependencies.
- Introducing Static Dependency Resolution!