New Mapping Interface

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Why Have A Mapping Interface?

- Scheduling is hard
- Lots of runtimes have heuristics
  - What do you do when they are wrong?
- Legion mapping interface exposes all these decisions
  - Customize decisions/heuristics for applications + machines

Old Mapping Interface

- Let's be honest: the current interface is not clean
- There are good reasons for this:
  - No one had ever designed a dynamic one before
  - We had no idea what we really wanted
- Result: evolutionary interface
  - No coherence in the design

New Mapping Interface

- We now have some experience writing mappers
- We know (mostly) what we want
- Time for a new interface with a coherent design

Mapper Call Format

```
struct MapTaskInput {
  …
};
struct MapTaskOutput {
  …
};
virtual void map_task(const Task &task,
                      const MapTaskInput &input,
                      MapTaskOutput &output) = 0;
```

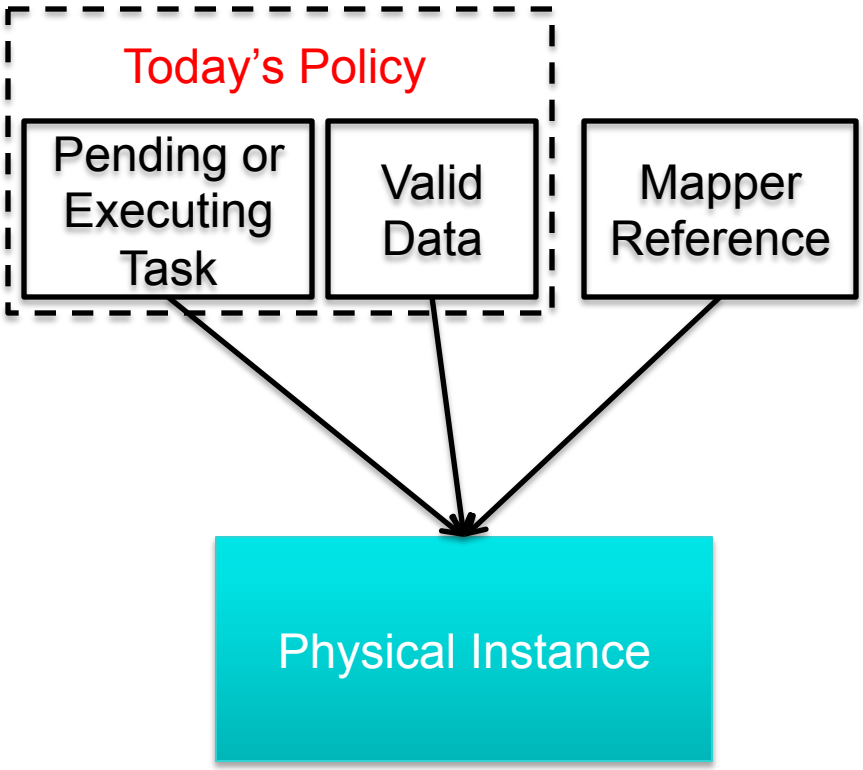
- Most mapper calls have three arguments
  - Reference to the operation (task, copy, inline mapping, etc)
  - Input argument struct
  - Output argument struct
- Clear delineation of inputs and outputs
- Extensible: can easily add new parameters

Physical Instances

- Old mapper based around memories
  - `std::vector<Memory> target_ranking;`
  - This was alright before logical regions had fields
- New mapper based around physical instances
  - `std::vector<PhysicalInstance> chosen_instances;`
  - Give explicit names to physical instances
  - No more guessing what the runtime does
- Consequences:
  - New way of managing creation/deletion of physical instances
  - New way of mapping tasks

Instance Management

- Mappers can hold references to instances
  - Have names for instances
  - Prevent de-allocation
- Mappers can request instances be reclaimed
  - For when memories are full
- Mapper call to rank instances that are ready for deletion



Specifying Data Layout

- Currently: Legion is minimally aware of layout
- Blocking factor: describe density of fields
- Two problems:
  - Insufficient for describing all interesting data layouts
  - Not captured as properties of task variants
- Need more expressiveness

Blocking Factor=1
Array-of-structs (AOS)

Blocking Factor=N
Struct-of-arrays (SOA)

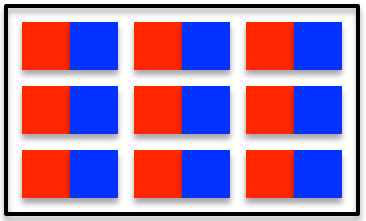
Blocking Factor=2
Hybrid

Layout Constraint Language

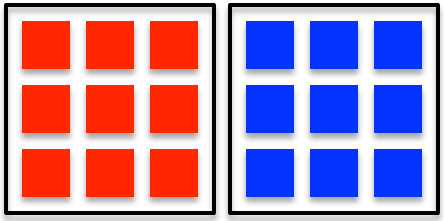
- A small set-constraint language

- Can describe the following:
  - Dimension ordering
  - Field ordering
  - Sub-dimensions for tiling
  - Alignment
  - Field offsets
  - Memory kinds
  - …

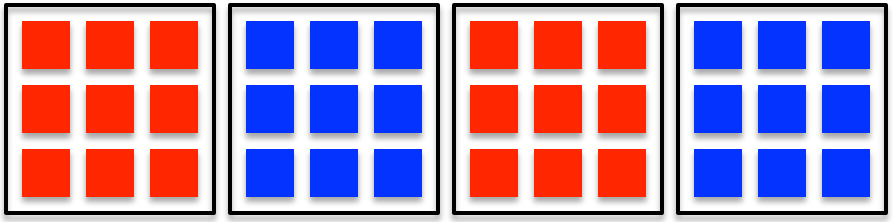
AOS, C-order



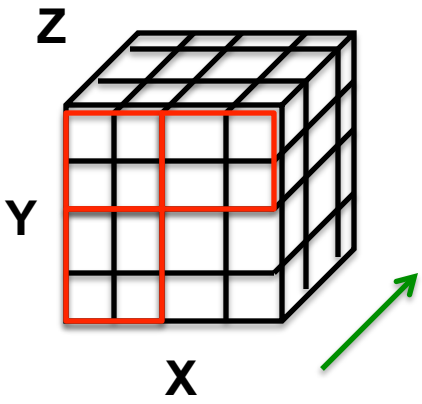
SOA, Fortran-order



2-D Slices



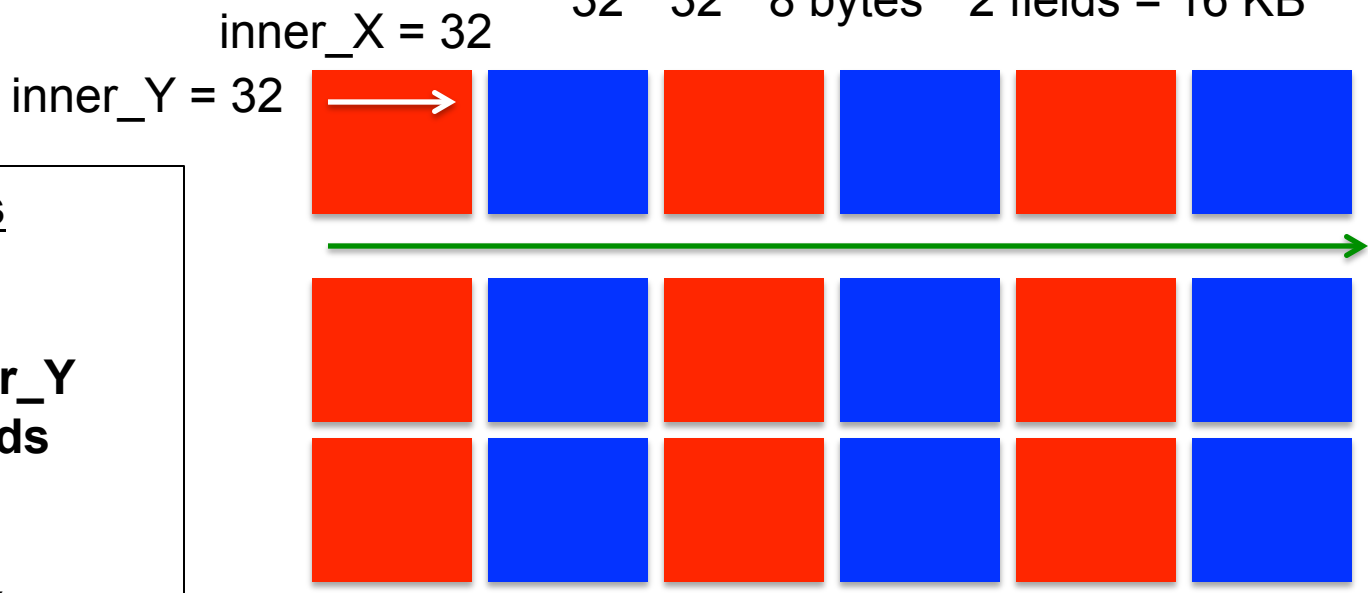
Layout Constraints Example



Task
2-D stencil
Two fields: A + B
Fields are 8 bytes

Machine
CPU w/ AVX
16 KB L1 cache

32 * 32 * 8 bytes * 2 fields = 16 KB



Constraints
split(X, 32)
split(Y, 32)
inner_X < inner_Y
inner_Y < fields
A < B
fields < Z
Z < outer_X
outer_X < outer_Y
align(inner_X, 32-bytes)

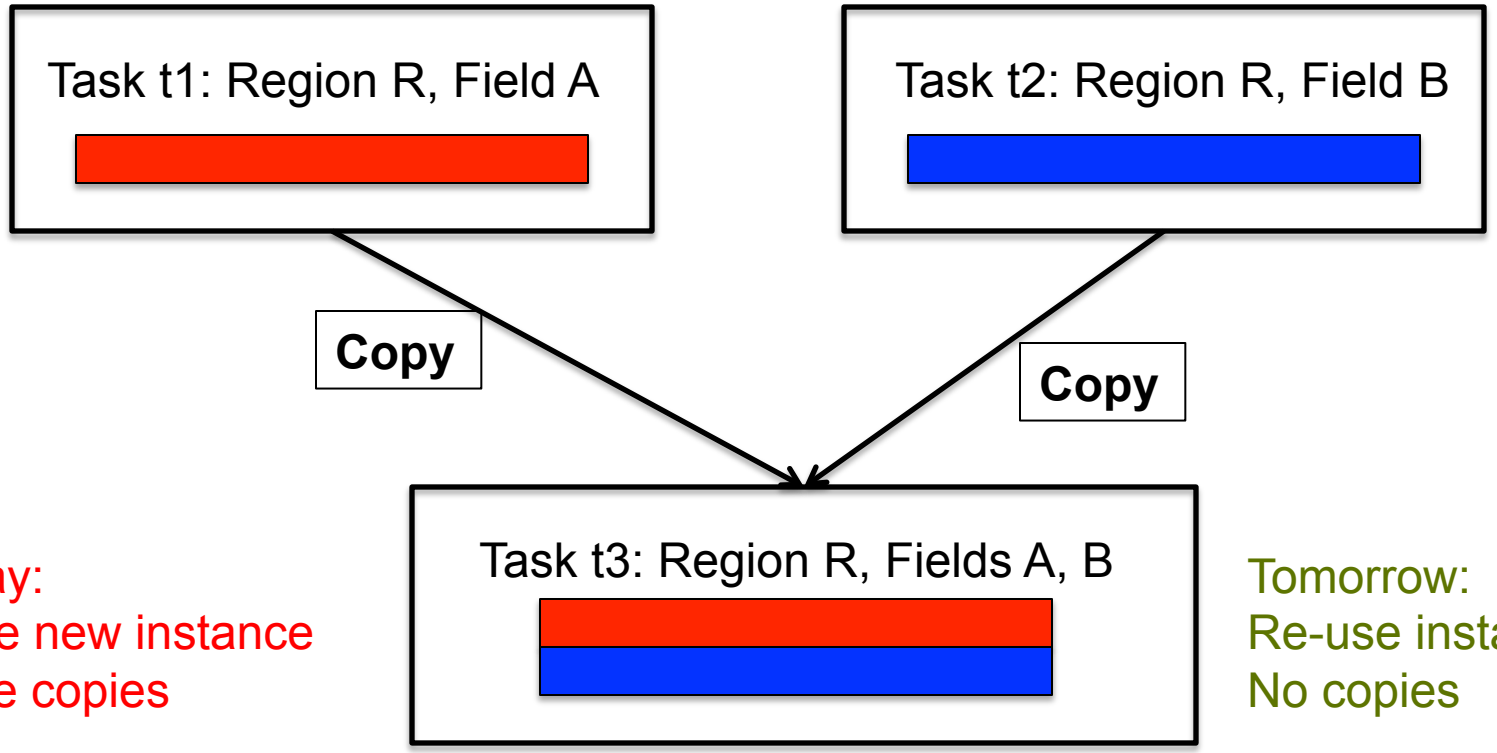
…

Why bother?

Legion DMA code automates data transformation

Satisfying Region Requirements

- Can satisfy region requirements with multiple instances
  - Today: only one instance per region requirement
  - Reduce the number of unnecessary copies



Today:
Make new instance
Issue copies

Tomorrow:
Re-use instances
No copies

Only works with SOA layouts

Satisfying Region Requirements

- **Map multiple region requirements to the same instance**
  - **Useful for pointers of type ptr(r1+r2+…)**
  - **No need for conditional statements on pointer dereferences**

Too Slow!

```
if (safe_cast<r1>(ptr))
   dereference in r1
else
   dereference in r2
```

Solution: put them in a big instance that is the union of r1+r2

```
*(ptr(r1+r2))
```

How do we guarantee correctness?

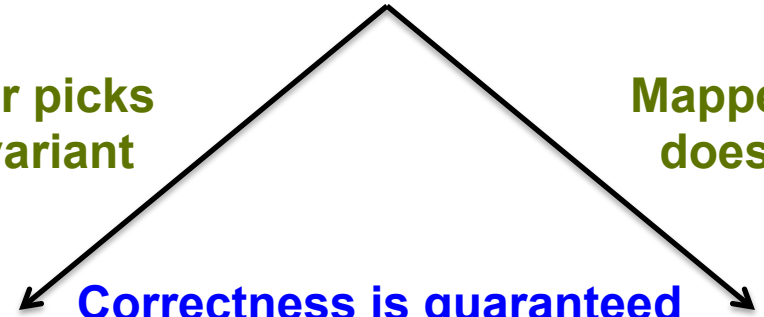
Task Variant Registration

- Need set constraint language for tasks too
  - Co-location constraints (regions mapped to the same inst)
  - Processor ISA (x86, Power, ARM, PTX, …)
  - Resource constrains (cache sizes, registers, …)
- New task variant registration API
  - Specify all constraints on task variant
  - Specify layout constraints on all region requirements
- Support for dynamic task variant registration
  - Anticipating DLLs and JIT

Mapping Tasks

- Mapping tasks is now a little different

- Mapper picks:
  - Processor on which to run
  - Instance(s) for all region requirements



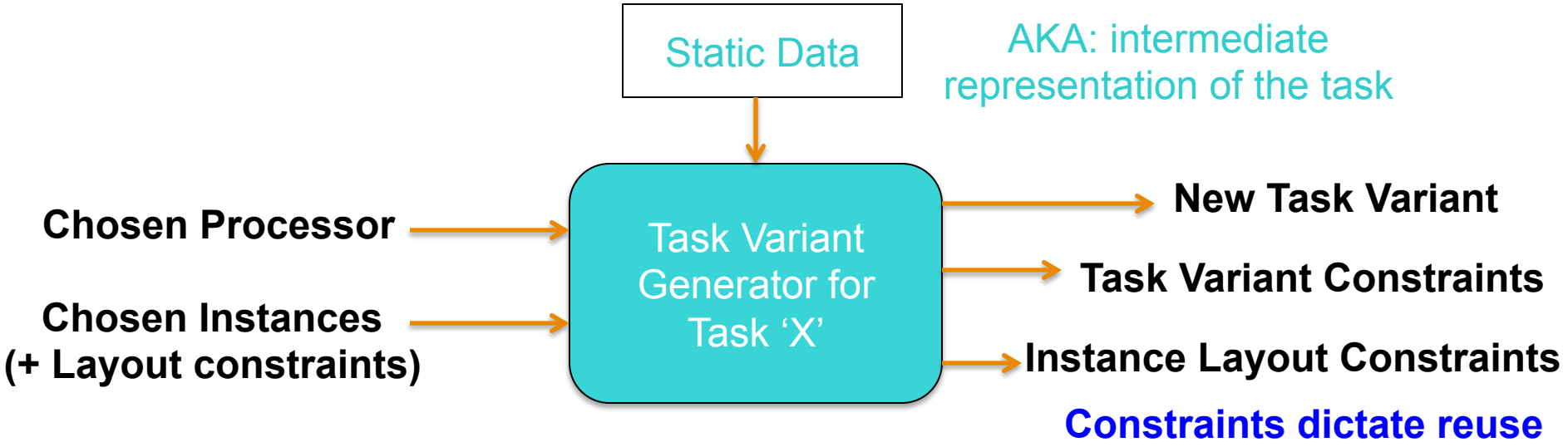
Runtime verifies all constraints are satisfied

Runtime picks variant with most closely satisfied constraints

What if it can't find one?

Task Generators

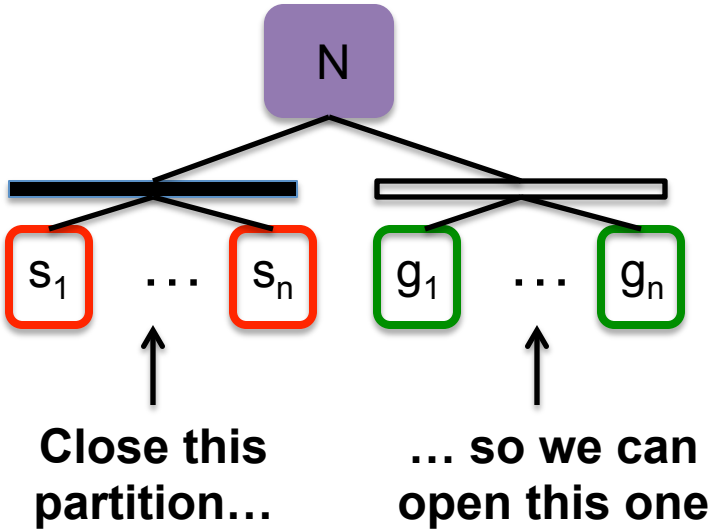
- What if we can't find a satisfactory variant?
  - Today: mapping failure -> retry
  - Better answer: make the right variant
- Task Variant Generators:
  - A function invoked by the runtime to generate a task variant
  - One registered for each kind of task (with optional static data)



A Generic Interface for Dynamic Compilation with Any Compiler

Dealing with Close Operations

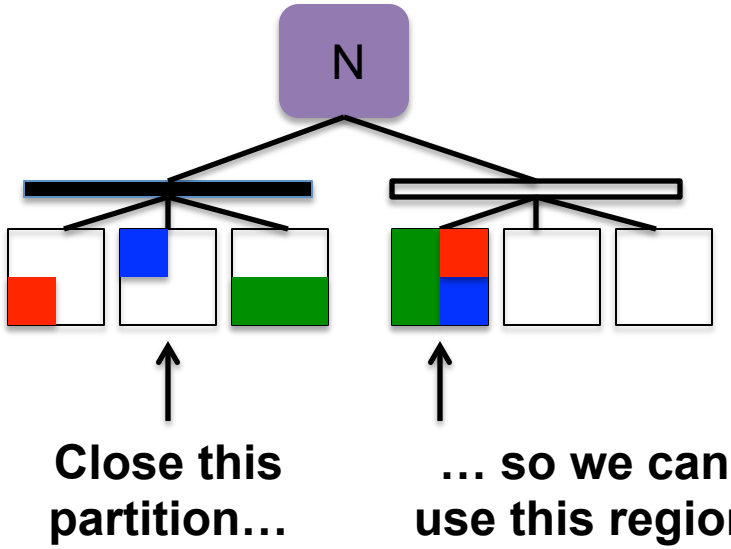
- Close operations move data between partitions
  - Automatically inserted by the runtime where needed
  - Normally transparent
- Except: rank_copy_targets
  - The most misunderstood and feared mapper call
  - Create physical instance(s) for close operations
  - Now gone!
- Replaced by map_close(…)



What if ‘N’ is really big and we don’t want to make a physical instance?

Composite Instances

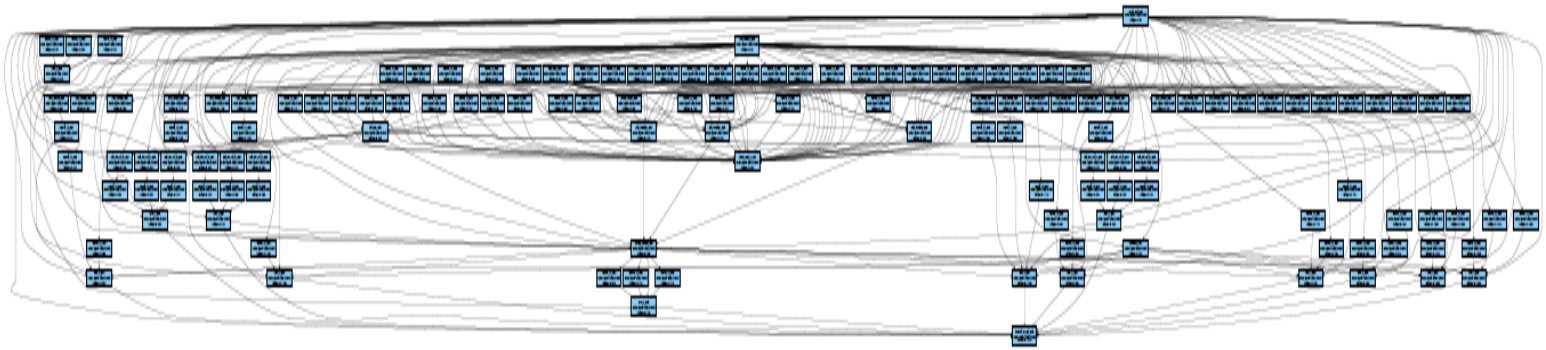
- Perform close without building a big instance
- Create composite instance
  - Snapshot of region tree
  - Capture existing instances
- Issue minimal copies from existing instances
  - Legion automatically performs intersection tests
  - Memoizes results



Can use this today:
return ‘true’ from
rank_copy_targets

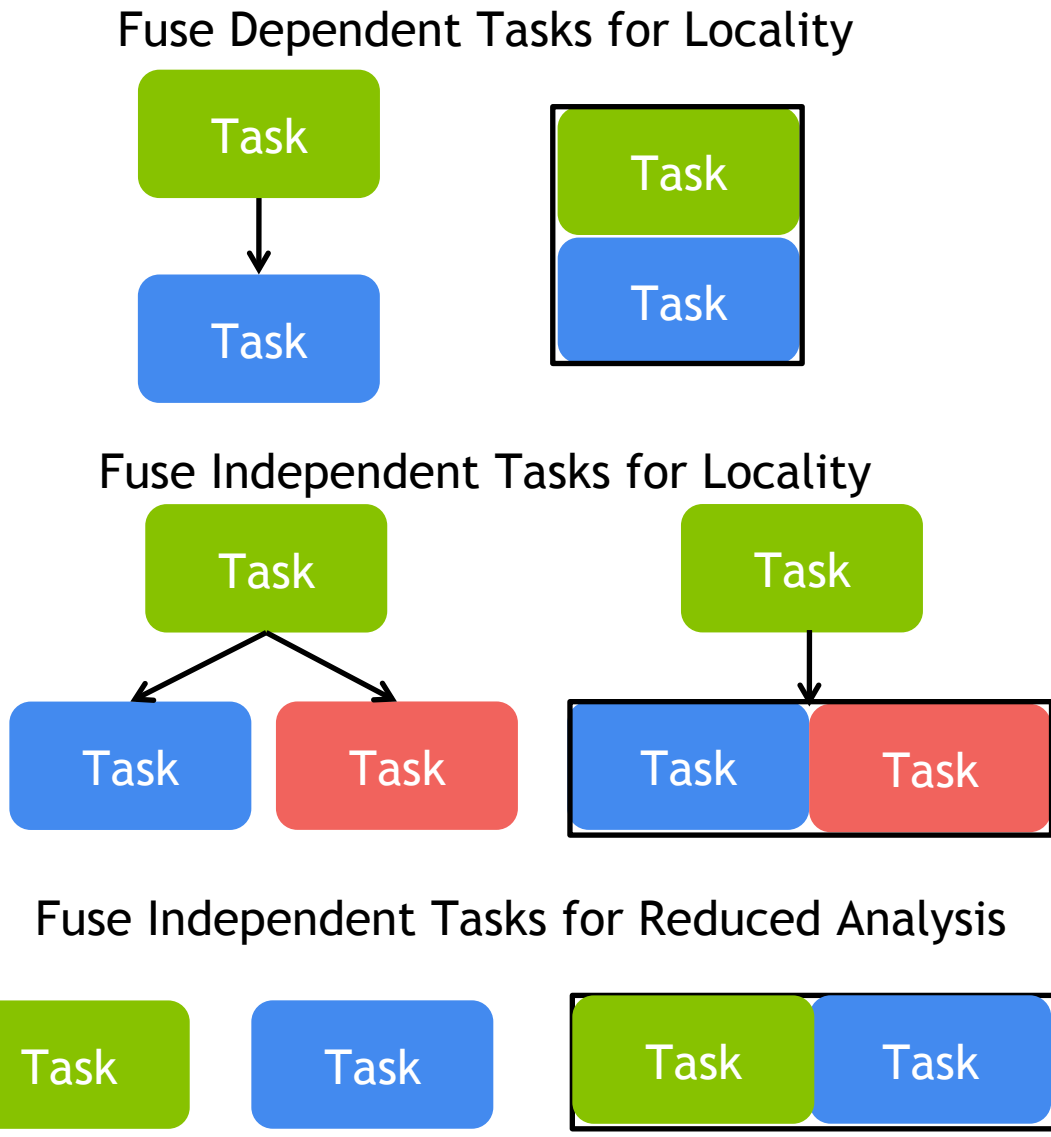
Manipulating Dependence Graphs

- Legion builds a dependence graph internally
  - Discovers all the parallelism possible
- How much is too much?
  - It depends
  - Make it a mapper decision
- Allow mapper to manipulate the dependence graph



Fusing Tasks

- Idea: let the mapper fuse tasks together
- Fusion: run tasks consecutively
  - Leverage locality
  - Amortize analysis costs
- Specialize by the kind of machine and graph shape

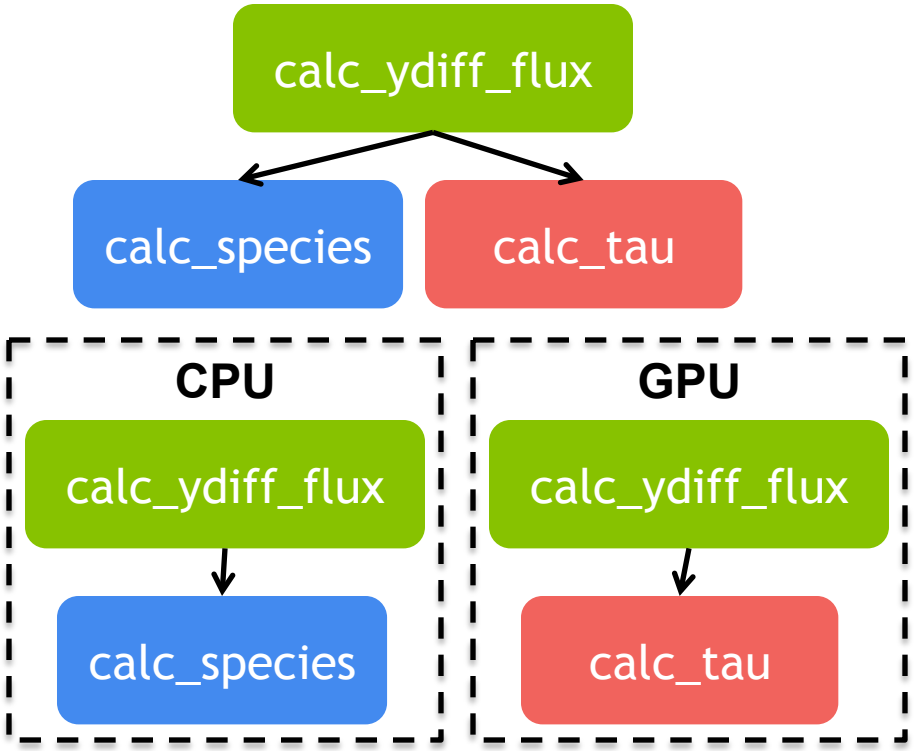


Replicating Tasks

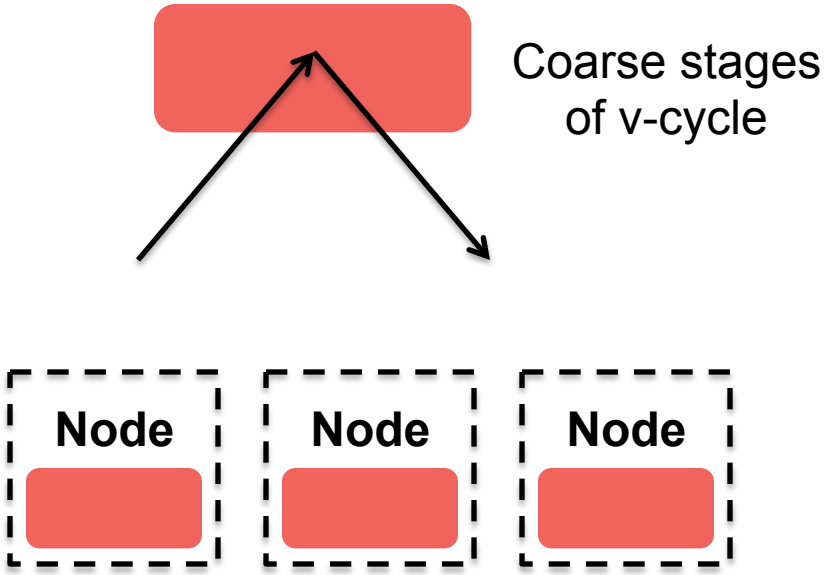
- **Replicate tasks to reduce communication**
  - **(or parallelize it)**

- **Works both within nodes and across nodes**

From S3D (intra-node)



From Multigrid (inter-node)



A New Default Mapper

A new mapper interface requires...

… a new default mapper implementation

- Better heuristics for management of data
- Better load balancing algorithms
- More generalized algorithms for constructing mappers

Bishop Mapping Language

C++ mapping interface is still verbose

Bishop: a language for mapping

Prototype version part of tomorrow's exercise

Open Mapper Questions

The mapper interface is still open for modifications

- What are the best ways to manage deferred execution?
- How do we compose multiple mappers?
- What are the best practices for mapper data structures?
- What are good abstractions for mapper construction?