Regent: Unstructured Regions

CS315B
Lecture 5

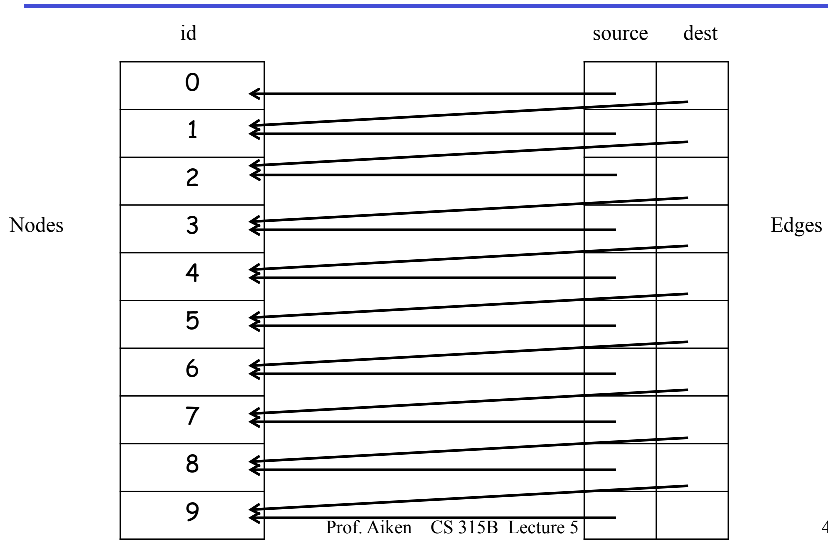
Regions Review

- *A region* is a (typed) collection
- Regions are the cross product of
  - An *index space*
  - A *field space*
- *A structured region* has a structured index space
  - E.g., int1d, int2d, int3d

new(…)

- Unstructured regions have a size
- But initially they have no elements
- Elements are allocated using new(…)
  - Occupies one (as yet) unallocated element of the region

Example 21



Partitioning

- Unstructured regions can be partitioned
- In particular, partitioning into equal size chunks works as expected.
- Example 20

Partitioning By Field

- A field can be used as a coloring
- Write elements of the color space into the field f
  - Using an arbitrary computation
- Then call partition(region.f, colors)
  - Example 27
  - Preferred to using explicit coloring objects

Partitioning, Digression

- Why do we want to partition data?
  - For parallelism
  - We will launch many tasks over many subregions

- A problem
  - We often need to partition multiple data structures in a consistent way
  - E.g., given that we have partitioned the nodes a particular way, that will dictate the desired partitioning of the edges

Dependent Partitioning

- Distinguish two kinds of partitions

- *Independent partitions*
  - Computed from the parent region, using, e.g.,
    - partition(equals, …)
    - partition(region.field, ...)

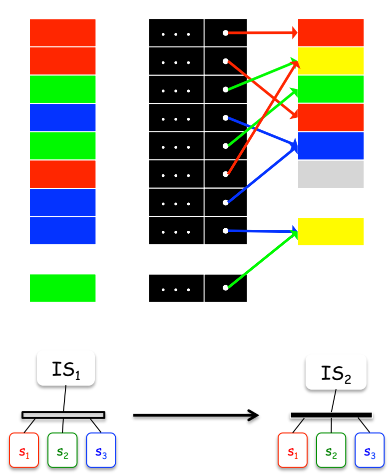
- *Dependent partitions*
  - Computed using another partition

Dependent Partitioning Operations

- Image
  - Use the image of a field in a partition to define a new partition
- Preimage
  - Use the pre-image of a field in a partition …
- Set operations
  - Form new partitions using the intersection, union, and set difference of other partitions

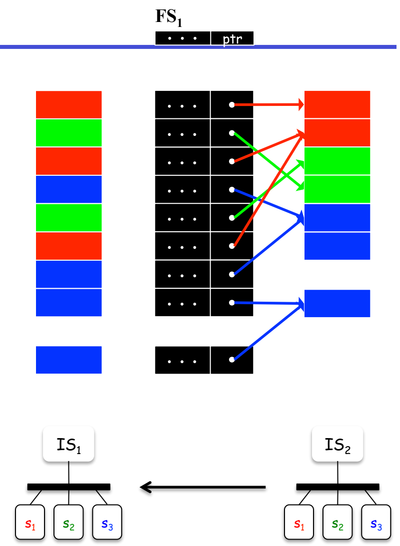
Image

- Computes elements reachable via a field lookup
  - Equivalent to *semi-join* in relational algebra
  - Can be applied to index space or another partition
  - Computation is distributed based on location of data
- Regent understands relationship between partitions
  - Can check safety of region relation assertions at compile time



Preimage

- Opposite of image – computes elements that reach a given subspace
  - Preserves disjointness
- Multiple images/preimages can be combined
  - can capture complex task access patterns
  - Limitation: no transitive reachability



Example 21

- Partition the nodes
  - Equal partitioning
- Then partition the edges
  - Preimage of the source node of each edge
- For each node subregion r, form a subregion of those edges where the source node is in r

Example 22

- Partition the edges
  - Equal partitioning
- Then partition the nodes
  - Image of the source node of each edge
- For each edge subregion r, form a subregion of those nodes that are source nodes in r

Discussion

- Note that these two examples compute the same partition
- Can derive the node partition from the edges, or vice versa

Example 23

- What would the example look like if we partitioned based on the destination node?
- Let’s find out …

Set Operations: Set Difference

- Partition the edges
  - Equal partition
- Compute the source and destination node partitions of the previous two examples
- The final node partition is the set difference
  - What does this compute?
  - Examples 24 & 25

Set Operations: Set Intersection

- Partition the edges
  - Equal partition
- Compute the source & destination node partitions
- Final node partition is the intersection
  - What does this compute?
  - Example 26

Example 28

- Same as the last example
- Once the final node partition is computed, compute a partition of the edges such that each edge subregion has only the edges connecting the nodes in the corresponding node subregion

Examples 29

- Pointers point into a particular region
  - And this is part of the pointer's type
- Partitioning can change which region(s) a pointer points to
  - May lead to typechecking issues, depending on which region you want to use for an operation

Example 30

- The right way to fix type issues is to use type casts
- Very analogous to downcasting from a more general object type to a more specific object type in an object-oriented language
- But, this solution does not currently work!
  - Casting of region types not yet implemented

Example 31

- The fix/workaround is to use wild in field space arguments when allocating regions
- Wild effectively turns off typechecking for those region arguments.

Backing Up …

- Regent's partitioning mechanisms are very different from other languages
- What do those other languages provide?

One Extreme: Simplicity

- PGAS languages (e.g. X10, UPC, Chapel) generally provide only simple array-based distribution methods
  - e.g. block, cyclic, blockcyclic
- Pros:
  - simple for programmer to describe
  - simple for compiler to verify consistency
  - simple for runtime to implement
- Cons:
  - no support for irregular (or even semi-regular) data structures
  - no support for irregular partitions of structured data
  - no support for aliased or multiple partitions

Other Extreme: Expressivity

- Initial Legion partitioning used general-purpose coloring object for ALL partitioning operations
  - Application able to color each element any way it wants
- Pros:
  - support for arbitrary irregularity in data and/or partitioning
  - support for aliased partitions, multiple partitions
- Cons:
  - significant programmer effort to describe even simple partitions
  - no ability for compiler to check that related regions are partitioned consistently
  - high runtime overhead for computing and querying partitions
  - manipulation of coloring was serial, limited to single node

Dependent Partitioning

- A carefully chosen middle ground between these two extremes
- Supports both structured and unstructured domains
- Allows arbitrary independent partitions to be computed by the application
  - But uses field data to capture intent rather than a coloring
  - Index-based partitions cover PGAS-like simple cases
- Provides an analyzable set of operations to compute dependent partitions from other partitions
  - Based on reachability and/or set operations
  - Consistency of dependent partitions can be verified at compile time
- And can be executed in parallel

Programmer Productivity

- Lines of code for computation of dependent partitions in Regent applications:

Application	Original LOC	Dependent Partitioning LOC	Reduction
PENNANT	163	6	96%
Circuit	159	8	95%
MiniAero	51	7	86%

- Not a perfect metric
  - Take with however much salt you like…

Summary

- The built-in partitioning operations are
  - Expressive
  - Can execute in parallel
  - Can be analyzed by the Regent implementation

- Except for explicit coloring objects
  - Inherently not parallel
  - Will eventually go away