Domain Map Improvements

Chapel Team, Cray Inc.

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Outline

- Stencil Distribution
- Sparse Block Distribution
- Bulk Add for Sparse Domains
- Locality Queries for Domains and Distributions
- Associative Domain Improvements
- Other Domain Map Improvements

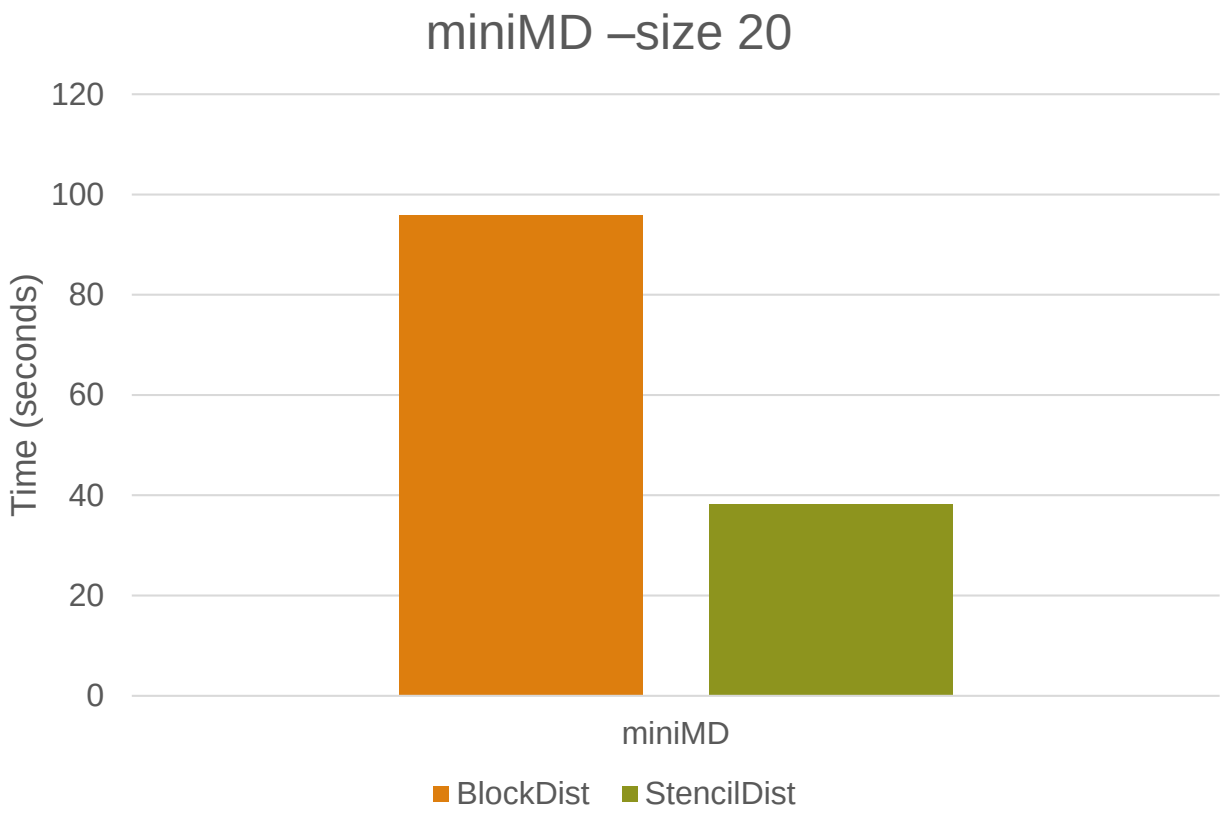
Stencil Distribution

StencilDist: Background

- **Block-like distribution that caches remote halo elements**
  - For a user-provided number of indices outside the domain
- **Useful because stencils access neighboring elements**
- **Initially developed during miniMD intern project**
  - Functional for miniMD, but buggy for other use cases
  - Lived under miniMD's source tree in previous releases
- **Occasional interest from external users**
  - Typically replied with "Cool! But be aware of bugs"
  - Having to copy the distribution from miniMD's directory was odd

StencilDist: Background

- **Much better miniMD performance compared to BlockDist**
  - 16 BW nodes on XC30



StencilDist: This Effort

- **Promoted StencilDist to $CHPL_HOME/modules/dists**
  - Makes it simple to "`use`" in a program
- **Improved testing**
  - Confirmed and exposed some embarrassing bugs
- **Bug fixes**
  - Slicing (used to drop cached elements)
  - Strided domains (had been completely broken)
  - Block-like view (now its own method)
    - Supports a view with no caching, easier to reason about reads/writes

StencilDist: Status and Next Steps

Status:

- Now a standard distribution
- No known correctness bugs

Next Steps:

- Improve performance
  - Look at some known locality issues
- Investigate new features
  - 6-face halo exchange vs. 27-point
  - Only cache on one side of an axis (PRK motivated)
- Possibly merge with BlockDist to create a single powerful distribution
- Move towards having compiler automatically insert communication

Sparse Block Distribution

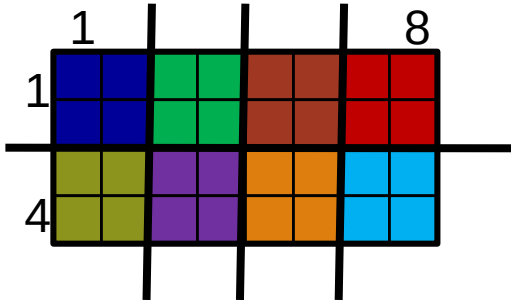
Sparse Block: Background

- **Sparse Block originally prototyped in fall 2012**
- **Supported distributed sparse arrays and domains**
  … but prototype fell by the wayside

- **Sparse Block implemented with the Block distribution**
  - the data distribution is the same
  - but store sparse local domains and arrays rather than dense

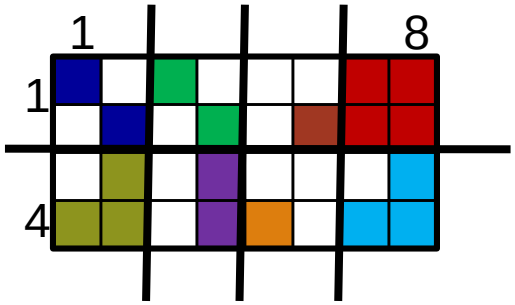
Sparse Block: Example

```
var Dom = {1..4, 1..8} dmapped Block( {1..4, 1..8} );
```



distributed to


```
var SparseDom : sparse subdomain(Dom);
var Indices = [(1,1), (2,2), (3,1), …]
SparseDom += Indices;
```



distributed to

Sparse Block: This Effort

- **Cleaned up the prototype from 2012 and get it working**
  - fixed compiler bugs
  - added missing features
- **Supports users of distributed sparse data structures**

Sparse Block: Status and Next Steps

Status:

- Basic functionality available
  - There may be missing features – not broadly tested yet
- bulkAdd or using += in bulk is critical to performance
- Available in 1.14 release

Impact: Enables sparse / distributed graph algorithms

Next Steps:

- Build more with sparse block
- Consider other ways of declaring sparse arrays and domains
- Further optimize communication for sparse block
- Investigate related compiler optimizations
- Explore distributions other than Block (e.g., recursive bisection)

Bulk Add for Sparse Domains

Bulk Add

Background: Often, += is used to add elements to a domain

```
var DenseDomain = {1..10};
var D: sparse subdomain(DenseDomain);
D += 1; D += 2; D += 3; D += 5; D += 7;
```

- but this approach has significant performance overhead
  - per-element locking, reallocating, sorting, communicating, resizing arrays

This Effort: sparse domains now support bulk addition

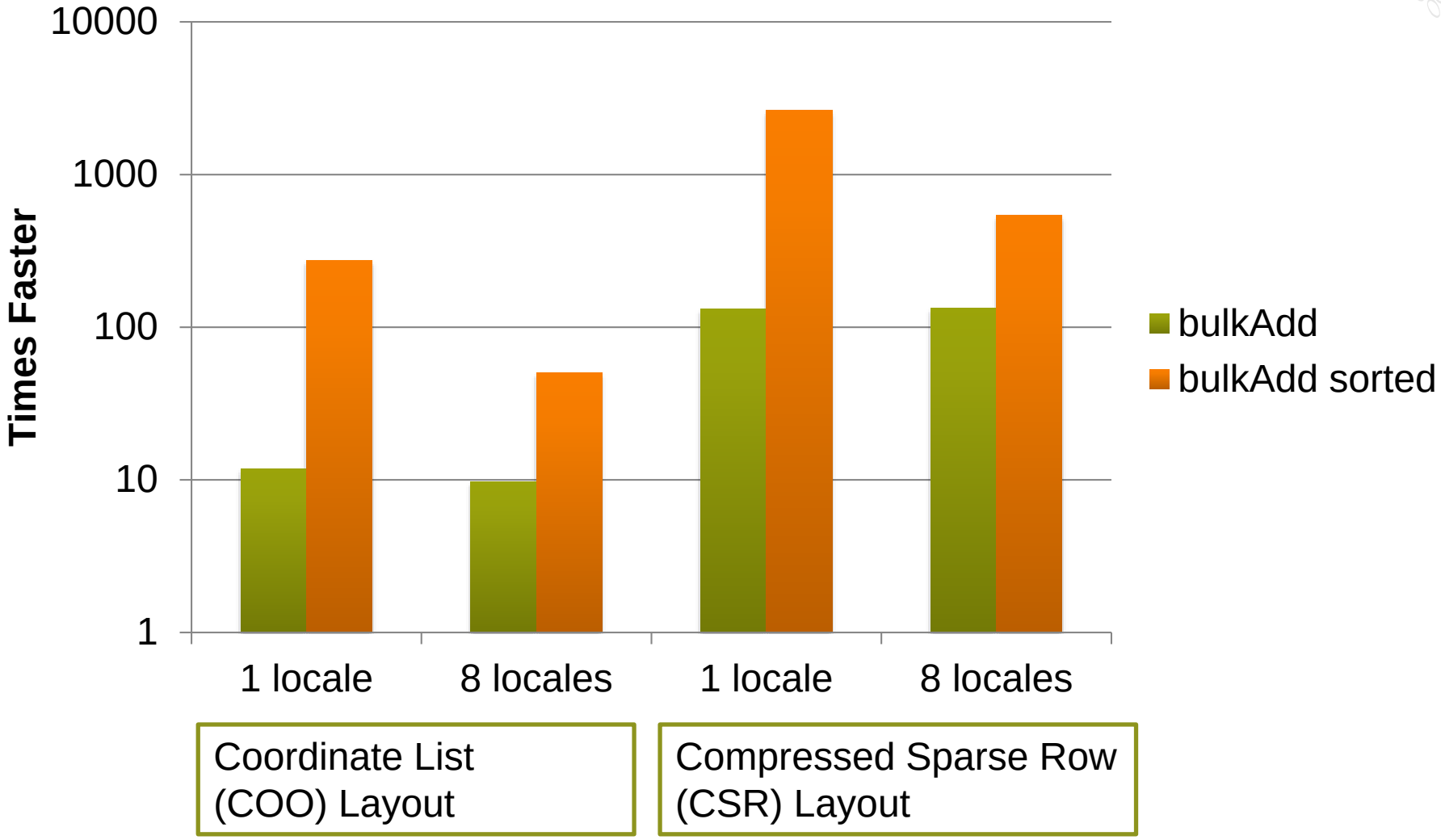
```
D += [1,2,3,5,7];
// or, for more control:
D.bulkAdd([1,2,3,5,7], dataSorted=true);
```

Impact: Greatly reduces overhead

Next Steps: Support bulkAdd efficiently on all irregular domains

- Associative and Opaque

Speedup from bulkAdd, adding 100000 indices



Locality Queries for Domains and Distributions

Locality Queries for Domains and Distributions

Background: Chapel supports locality-based queries on arrays

```
A.targetLocales()                 // returns the locales grid
A.getLocalSubdomain()             // returns the single local portion, if possible
A.getLocalSubdomains()            // iterates over all local portions
A.hasSingleLocalSubdomain()       //  check if getLocalSubdomain can be called
```

- these were only supported on arrays

This Effort: Added these operations to domains and distributions

Impact: Arrays no longer required to make these queries

	distribution	domain	array
.targetLocales()	✓	✓	✓
.getLocalSubdomain() .getLocalSubdomains()		✓	✓

Associative Domain Improvements

Associative Domain Sizes

Background: Associative domains implemented via a hash table

- implemented with quadratic probing
  - uses a table of prime numbers
- these primes previously stopped at about 2 billion elements,
  - this limited the size of associative domains

This Effort: Improve the primes used by associative domains

- primes now go up to 2^{60}
- primes selected to maximize usage of jemalloc allocation blocks

Impact: Larger associative domains are possible

Next Steps: Consider supporting different hash table algorithms

requestCapacity on Associative Domains

Background: requestCapacity existed but wasn't documented

- useful when adding many elements to an associative domain
- can be used to minimize the number of reallocations

```
var D: domain(int);
D.requestCapacity(n); // indicate n elements will be added
for i in 1..n {
  D += computeElement(i);
}
```

This Effort: Adds documentation for requestCapacity

Impact: requestCapacity now available to Chapel users

Next Steps: Support requestCapacity on other irregular domains

Distributed Associative Domains/Arrays (WIP)

Background: Distributed associative support has been missing

- associative domains require distinct distributions
  - e.g., Block doesn't make sense for a domain(string)
- a prototype was developed in 2009 but was only partially functional
  - concept: user provides a value→locale mapper object

This Effort: Clean up distributed associative implementation

```
proc Map.indexToLocaleIndex(ind, targetLocs: [] locale): int
var D: domain(string) dmapped
      new UserMapAssoc(idxType=string, mapper=new Map());
```

Impact: Supported multi-locale label propagation study

Next Steps:

- Promote to modules/distributions
- Improve performance

Other Domain Map Improvements

Other Domain Map Improvements

- **Block distributions support strided bounding box args**
  - previously, bounding boxes had to be non-strided

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