Chapel: Locality and Affinity

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Outline

- Multi-Locale Basics
  - Locales
  - On, here, and communication
- Distributed Domains and Arrays

The Locale Type

- Definition
  - Abstract unit of target architecture
  - Capacity for processing and storage
  - Supports reasoning about locality
- Properties
  - Locale's tasks have uniform access to local memory
  - Other locale's memory is accessible, but at a price
- Examples
  - A multi-core processor
  - An SMP node

Program Startup

- Execution Context

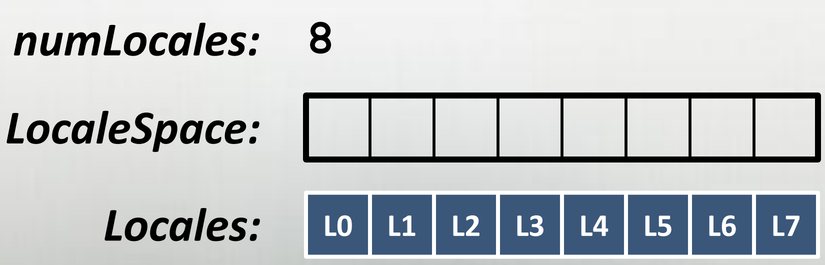
```
config const numLocales: int;
const LocaleSpace: domain(1) = [0..numLocales-1];
const Locales: [LocaleSpace] locale;
```

- Specify # of locales when running executable

```
prompt> a.out --numLocales=8
```

Alternatively,

```
prompt> a.out -nl 8
```

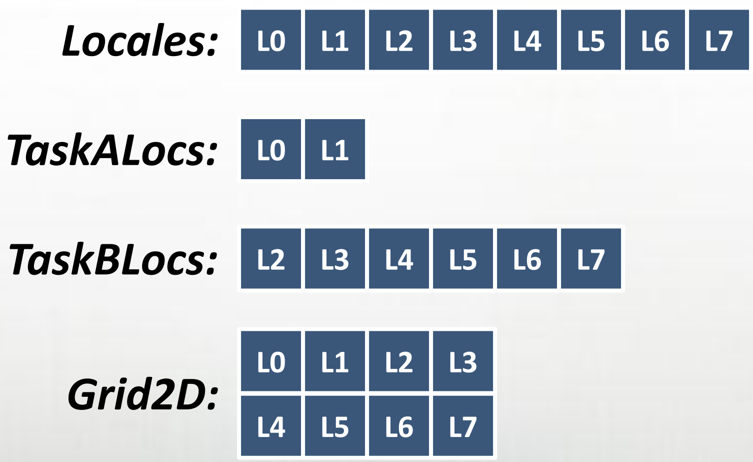


Rearranging Locales

Create locale views with standard array operations:

```
var TaskALocs = Locales[0..1];
var TaskBLocs = Locales[2..numLocales-1];

var Grid2D = Locales.reshape([1..2, 1..4]);
```



Locale Methods

- ```
  def locale.id: int { ... }
  ```
  Returns index in LocaleSpace
- ```
  def locale.name: string { ... }
  ```
  Returns name of locale (like uname -a)
- ```
  def locale.numCores: int { ... }
  ```
  Returns number of cores available to locale
- ```
  def locale.physicalMemory(...) { ... }
  ```
  Returns physical memory available to locale

  Example
  ```
  const totalSystemMemory =
    + reduce Locales.physicalMemory();
  ```

The On Statement

- Syntax

```
on-stmt:
  on expr { stmt }
```

- Semantics
  - Executes *stmt* on the locale specified by *expr*
  - Does not introduce concurrency
- Example

```
var A: [LocaleSpace] int;
coforall loc in Locales do on loc do
  A(loc.id) = compute(loc.id);
```

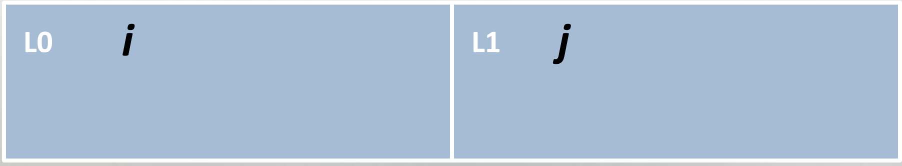
Querying a Variable's Locale

- Syntax

```
locale-query-expr:
  expr . locale
```

- Semantics
  - Returns the locale on which *expr* is allocated
- Example

```
var i: int;
on Locales(1) {
  var j: int;
  writeln(i.locale.id, j.locale.id); // outputs 01
}
```



Here

- Built-in locale

```
const here: locale;
```

- Semantics
  - Refers to the locale on which the task is executing
- Example

```
writeln(here.id);     // outputs 0
on Locales(1) do
  writeln(here.id);   // outputs 1
```

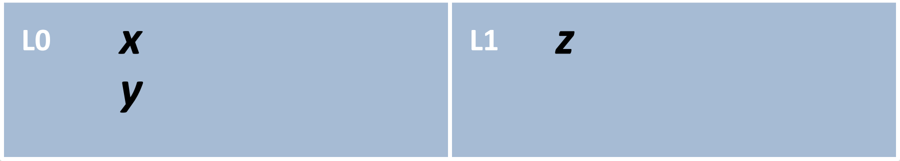
Serial Example with Implicit Communication

```
var x, y: real;         // x and y allocated on locale 0

on Locales(1) {         // migrate task to locale 1
  var z: real;          // z allocated on locale 1

  z = x + y;            // remote reads of x and y

  on Locales(0) do      // migrate back to locale 0
    z = x + y;          // remote write to z
                        // migrate back to locale 1
  on x do               // data-driven migration to locale 0
    z = x + y;          // remote write to z
                        // migrate back to locale 1
}                       // migrate back to locale 0
```



The Fragmented Model in Chapel

```
def main() {
  coforall loc in Locales do on loc {
    myFragmentedMain();
  }
}

def myFragmentedMain() {
  const size = numLocales, rank = here.id;
  ...
```

Outline

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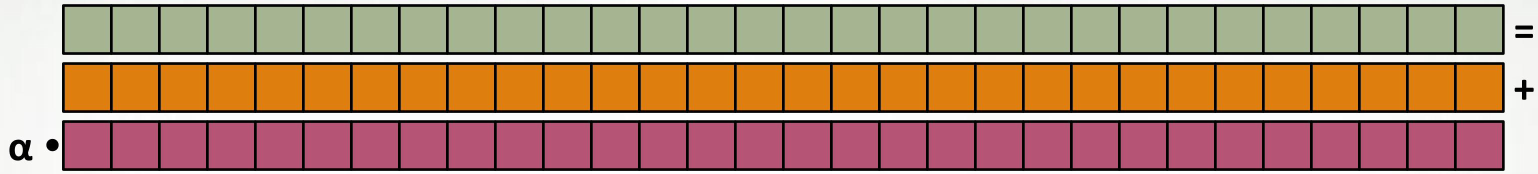
- Distributed Domains and Arrays

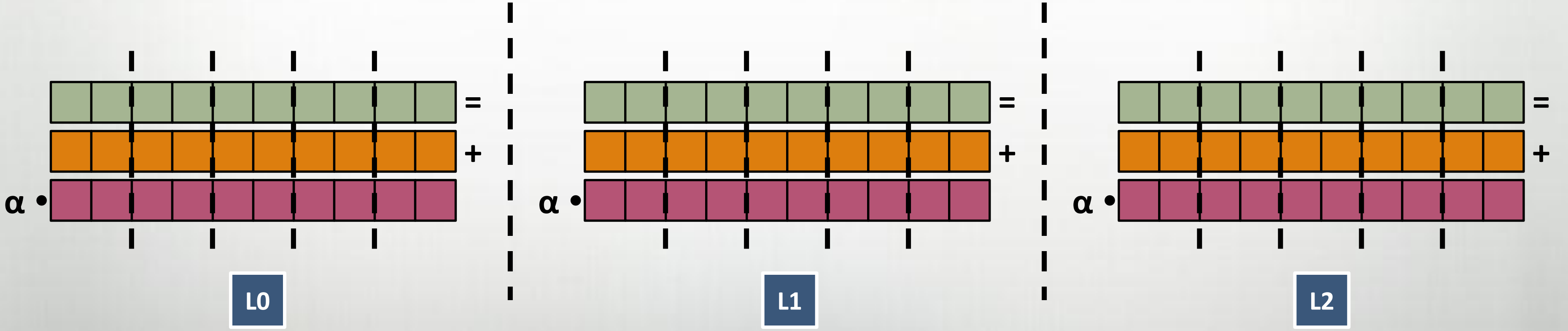
What is a Distribution?

A "recipe" for distributed arrays that...

Instructs the compiler how to Map the global view...



...to a fragmented, per-processor implementation

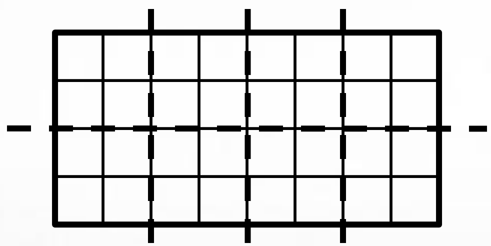


Distributing a Domain

Domains are associated to a distribution

```
const Dist = new Block(rank=2, bbox=[1..4, 1..8]);

var Dom: domain(2) distributed Dist = [1..4, 1..8];
```



distributed over

The distribution defines:

- Ownership of domain indices and array elements
- Default distribution of work (task-to-locale map)
  - E.g., forall loops over distributed domains/arrays

Authoring Distributions

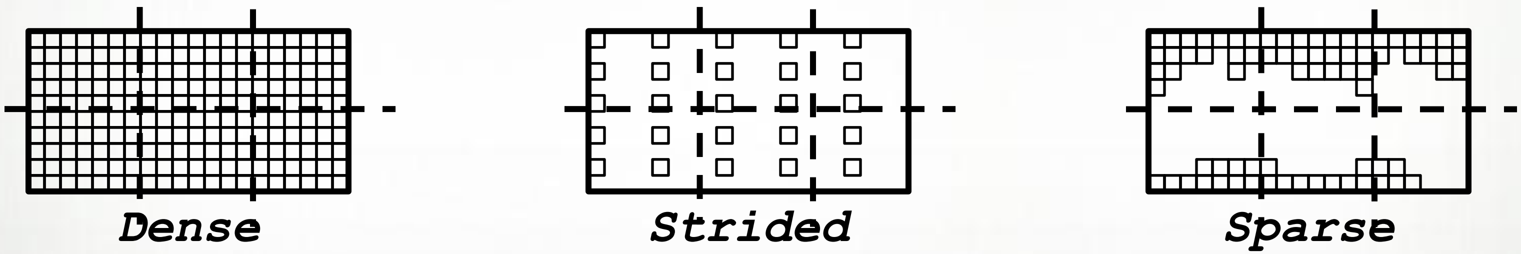
- (Advanced) programmers can write distributions
- Built-in library of distributions
  - No extra compiler support for built-in distributions
  - Compiler uses structural interface:
    - Create domains and arrays
    - Map indices to locales
    - Access array elements
    - Iterate over indices/elements sequentially, in parallel, zippered
    - ...
- Distributions are built using language-level concepts
  - On for data and task locality
  - Begin, cobegin, and coforall for data parallelism

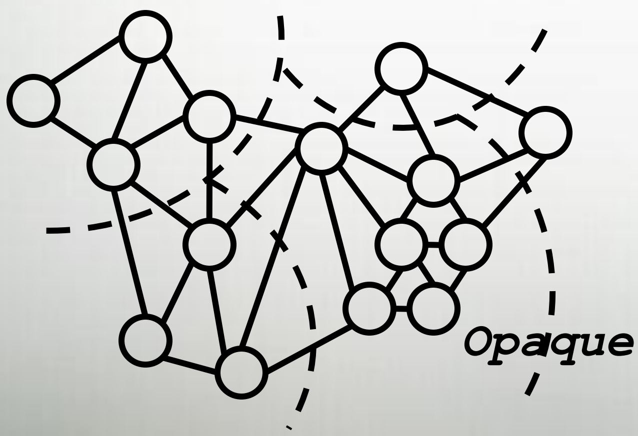
Distributing Domains

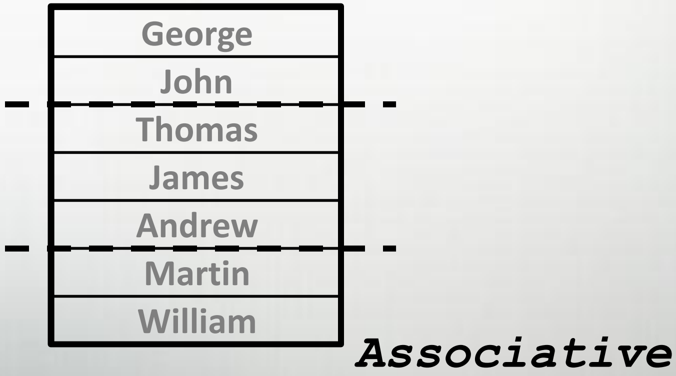
All domain types can be distributed.

Semantics are independent of distribution.

(Though performance and parallelism will vary...)







Questions?

- Multi-Locale Basics
  - Locales
  - On, here, and communication
- Domain and Array Distributions