An Overview of Chapel

Jonathan Turner
University of Colorado at Boulder
(Cray Summer Intern 2010)

Before we get started

- This talk is an overview of some of Chapel's unique features, later talks will go into more detail

- *Disclaimer: This presentation assumes the newest, yet unreleased, Chapel syntax, so there are keyword differences with the latest released version of the language*

What is Chapel?

- Modern distributed, parallel (and concurrent) language
  - Uses partitioned global address space (PGAS) as its communication layer
  - Includes affinity control
- Compiled, general purpose language
  - Has many of the conveniences of a dynamic language
- Has first-class support for multidimensional arrays, as well as sparse and strided arrays
- Open-source implementation
  - Available now at https://sourceforge.net/projects/chapel/

What are Chapel's Goals?

- Main Goal: Improve programmer productivity
  - Improve the programmability of parallel computers
  - Match or beat the performance of current programming models
  - Provide better portability than current programming models
  - Improve robustness of parallel codes
- Be familiar to the seasoned Fortran/C/C++ developer as well as the new crop of Java/Matlab/Python programmers
  - Allows both OOP and traditional imperative styles
- Allow users to work with algorithms and concurrency at various levels of detail

A source-driven

OVERVIEW OF CHAPEL

Generics

```
proc add_or_concat(x, y) {
  return x + y;
}

writeln(add_or_concat(3, 4));
writeln(add_or_concat(“3”, “4”));
```

- One function can mean many things
- Compiler works with what you call the function with
- The example prints the number 7 followed by the string “34”

Tuples

```
var y: 3*int = (4, 5, 6);

var (a, b, c) = y;
//assigns a=4, b=5, c=6

var d = ((...y), (...y));
//d = (4, 5, 6, 4, 5, 6)

var z = y + y;
//z = (8, 10, 12)
```

- Tuples are a powerful first-class citizen in Chapel
- Allow for destructuring, expansion, and a number of operations (including lexicographical ordering)

Iterators

```
iter squares(n:int) : int {
  for i in 1..n do
    yield i * i;
  }
}

for s in squares(10) {
  writeln(s);
}
```

- Iterators are like functions but produce a “stream” of values
- Can be used in **for** statements

…AND THEN THE FUN BEGINS

Task Parallelism: Sync and Begin

```
sync {
  begin treeSearch(root);
}

proc treeSearch(node) {
  if node == nil then return;
  begin treeSearch(node.right);
  begin treeSearch(node.left);
}
```

- `sync` joins all `begin` commands
- Much more implicit than dealing with threads and locks
- Also more composable than threads and locks

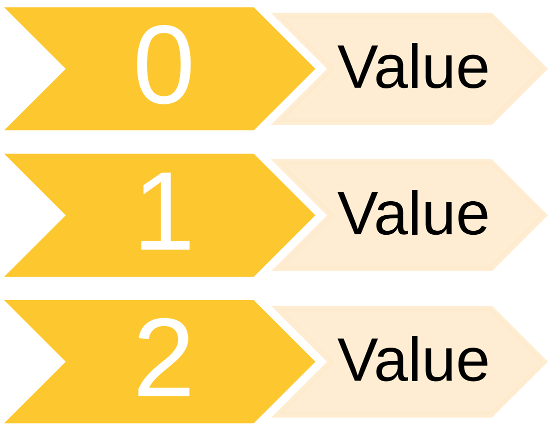
Forall and Coforall

```
for x in 1..n do
  expensive_operation(x);

forall x in 1..n do
  expensive_operation(x);

coforall x in 1..n do
  expensive_operation(x);
```

- Like **for**, but now each iteration can be done in parallel
- **forall** hints that each iteration can be done in parallel using a “recipe” but the loop must be serializable
- **coforall** requires that each iteration be done in parallel

A New Way of Looking at Indices

Traditional



Chapel

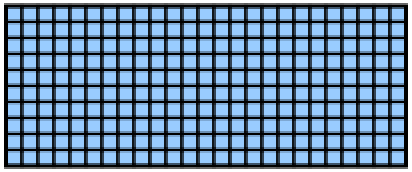
Domains

```
var D: domain(1) = [1..1000];
var a: [D] int;
var b: [D] string;

a[5] = 10;
b[5] = “test”;

var D: domain(2) = [1..m,
   1..n];

var Inner: subdomain(D) =
   [2..m-1, 2..n-1];

var Strided = D by (2, 2);
```

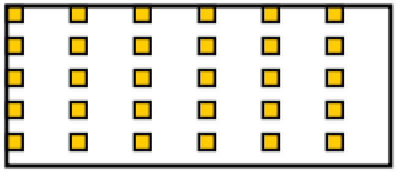
- Abstract index sets
- For example: 1-based or 0-based, you pick
- Can be strided, multi-dimensional
- Can also span multiple machines (which we’ll see later)
- First example can also be written: `var a: [1..1000] int`

Domains Come in Many Shapes

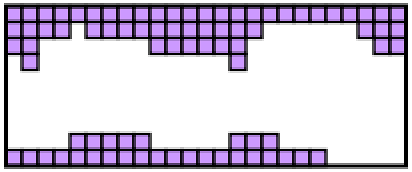
```
var D: domain(2) =
  [1..m, 1..n];
```

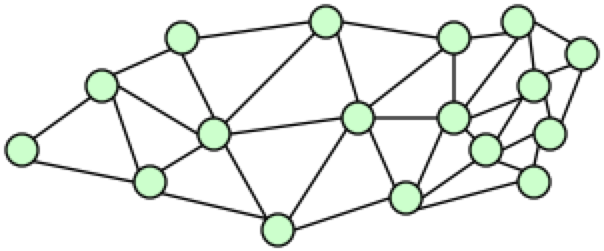


```
var Strided =
  D by (2, 4);
```

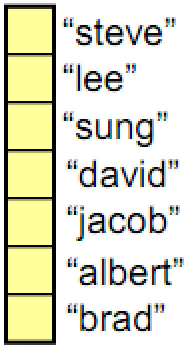


```
var Sparse:
sparse subdomain(D);
```



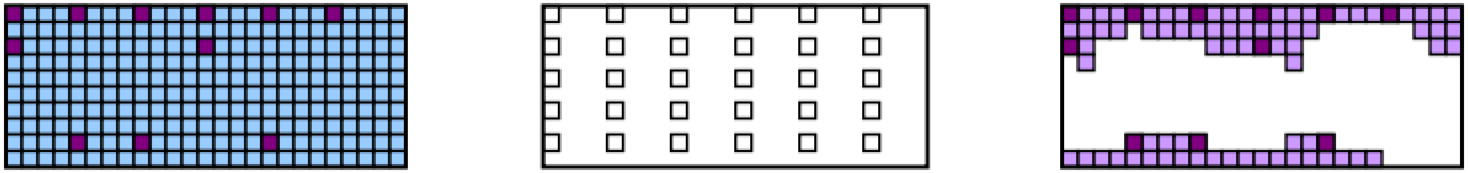


```
var Vertices:
domain(Vertex);
```




```
var Names:
domain(string);
```

…and Support Set-like Operations



Domain Intersection

Associative Domains

```
var D: domain(int);
D.add(3);
D.add(5);

var a: [D] int;
var b: [D] string;

a[3] = 100;
b[5] = “test”;

var D2: domain(Shape);
D2.add(triangle);
D2.add(square);
```

- We can now handle arbitrary indices, not just ones based on a range of values
- Work like other arrays, we can iterate through it just as simply
- Also works with any value type, not just integers and integers

Domain Maps

```
use CyclicDist;

const tpl = 2;

var myCyclicDist =
  new dmap(new Cyclic(
  startIdx=(1,1)
  dataParTasksPerLocale=tpl));

var dom :
  domain(2) dmapped myCyclicDist =
  [1..n, 1..n];
```

- Domain maps allow us to connect our domain to multiple processing units
- Domain maps can pick from a variety of distribution methods (Cyclic distribution shown)
- Users can create their own distributions

Summary

- Chapel has a lightweight, familiar syntax
- It has powerful abstractions that let us handle arrays and their indices in new ways
- These abstractions allow the user to focus on the problem and the distribution separately

Thank You.

Questions?