Chapel Boot Camp

(Everything you need to know about Chapel to understand CHIUW 2015*)

Brad Chamberlain, Cray Inc.

June 13, 2015

CHIUW 2015

* that I could cram into 30 minutes

Chapel Motivation

Q: Why doesn't parallel programming have an equivalent to Python / Matlab / Java / C++ / __(your favorite programming language here)__?

- one that makes it easy to quickly get codes up and running
- one that is portable across system architectures and scales
- one that bridges the HPC, data analysis, and mainstream communities

A: We believe this is due not to any particular technical challenge, but rather a lack of sufficient…

…long-term efforts
…resources
…community will
…co-design between developers and users
…patience

Chapel is an attempt to break this trend

What is Chapel?

- **An emerging parallel programming language**
  - Design and development led by Cray Inc.
    - in collaboration with academia, labs, industry; domestically & internationally

- **A work-in-progress**

- **Goal: Improve productivity of parallel programming**

What does "Productivity" mean to you?

Recent Graduates:

"something similar to what I used in school: Python, Matlab, Java, …"

Seasoned HPC Programmers:

"that sugary stuff that I don't need because I ~~was born to suffer"~~ want full control to ensure performance"

Computational Scientists:

"something that lets me express my parallel computations without having to wrestle with architecture-specific details"

Chapel Team:

"something that lets computational scientists express what they want, without taking away the control that HPC programmers need, implemented in a language as attractive as recent graduates want."

Chapel's Implementation

- **Being developed as open source at GitHub**
  - Licensed as Apache v2.0 software

- **Portable design and implementation, targeting:**
  - multicore desktops and laptops
  - commodity clusters and the cloud
  - HPC systems from Cray and other vendors
  - *in-progress:* manycore processors, CPU+accelerator hybrids, …

Outline

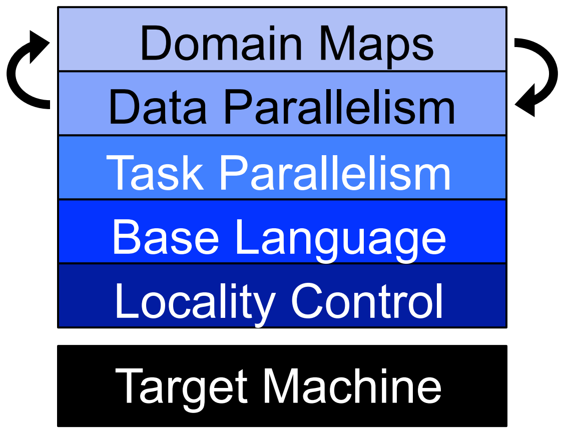
- ✓ Chapel Motivation and Background
- ➢ Chapel in a Nutshell
- Chapel Project: Past, Present, Future
- Chapel Resources

Multiresolution Design

Multiresolution Design: **Support multiple tiers of features**

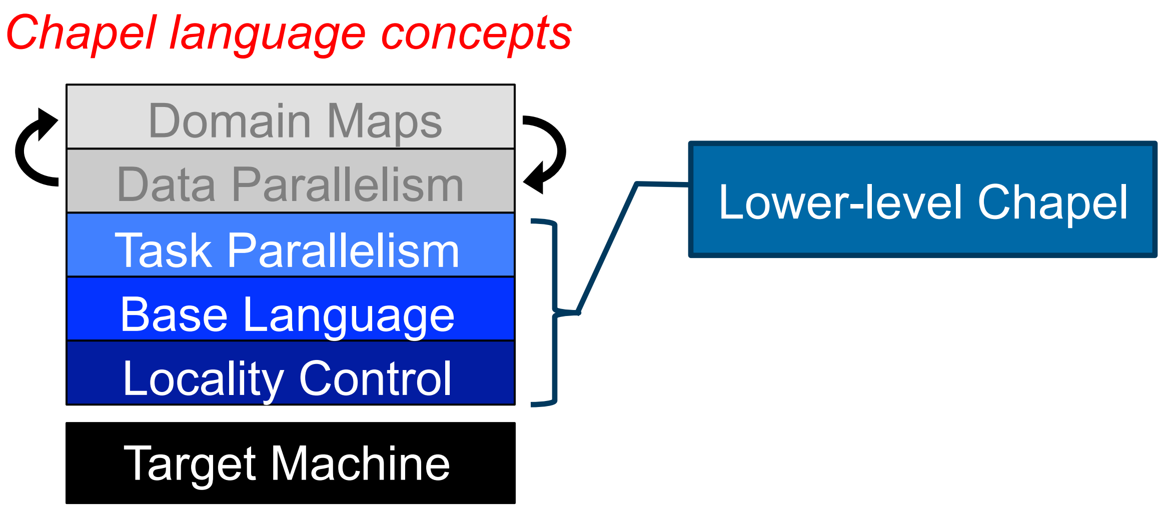
- higher levels for programmability, productivity
- lower levels for greater degrees of control

Chapel language concepts



- build the higher-level concepts in terms of the lower
- permit the user to intermix layers arbitrarily

Lower-Level Features



Chapel in a Nutshell: Base Language

```
iter fib(n) {
  var current = 0,
      next = 1;

  for i in 1..n {
    yield current;
    current += next;
    current <=> next;
  }
}
```

```
for (i,f) in zip(0..#n, fib(n)) do
  writeln("fib #", i, " is ", f);
```

```
fib #0 is 0
fib #1 is 1
fib #2 is 1
fib #3 is 2
fib #4 is 3
fib #5 is 5
fib #6 is 8
…
```

Chapel in a Nutshell: Base Language

CLU-style iterators

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  var current = 0,
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Chapel in a Nutshell: Base Language

Static Type Inference for:
- arguments
- return types
- variables

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range types and operators

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    current <=> next;
  }
}
```

swap operator

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zippered iteration

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Chapel in a Nutshell: Task Parallelism, Locality

taskParallel.chpl

```
coforall loc in Locales do
  on loc {
    const numTasks = here.maxTaskPar;
    coforall tid in 1..numTasks do
      writef("Hello from task %n of %n "+
             "running on %s\n",
             tid, numTasks, here.name);
  }
```

```
prompt> chpl taskParallel.chpl -o taskParallel
prompt> ./taskParallel --numLocales=2
Hello from task 1 of 2 running on n1033
Hello from task 2 of 2 running on n1032
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Chapel in a Nutshell: Task Parallelism, Locality

High-Level
Task Parallelism

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Abstraction of System Resources

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Chapel in a Nutshell: Task Parallelism, Locality

Locality/Affinity Control

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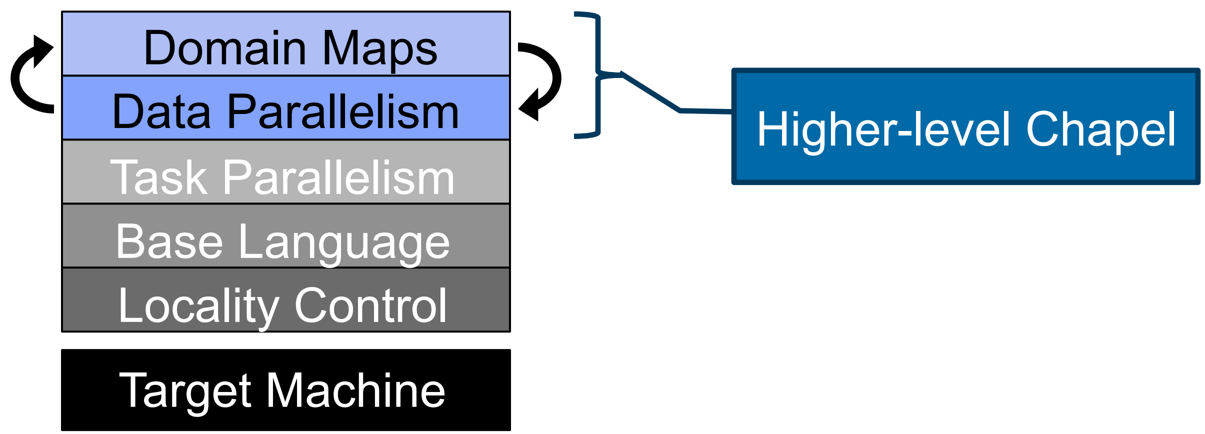
Higher-Level Features

Chapel language concepts



Chapel in a Nutshell: Data Parallelism

dataParallel.chpl

```
use CyclicDist;
config const n = 1000;
var D = {1..n, 1..n}
          dmapped Cyclic(startIdx = (1,1));
var A: [D] real;
forall (i,j) in D do
  A[i,j] = i + (j - 0.5)/n;
writeln(A);
```

```
prompt> chpl dataParallel.chpl -o dataParallel
prompt> ./dataParallel --numLocales=4 --n=5
1.1 1.3 1.5 1.7 1.9
2.1 2.3 2.5 2.7 2.9
3.1 3.3 3.5 3.7 3.9
4.1 4.3 4.5 4.7 4.9
5.1 5.3 5.5 5.7 5.9
```

Chapel in a Nutshell: Data Parallelism

Domains (First-Class Index Sets)

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Chapel in a Nutshell: Data Parallelism

Arrays

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Chapel in a Nutshell: Data Parallelism

Data-Parallel Forall Loops

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Domain Maps (Map Data Parallelism to the System)

```
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Parallelism and Locality: Orthogonal in Chapel

- **This is a parallel, but local program:**

```
begin writeln("Hello world!");
writeln("Goodbye!");
```

Parallelism and Locality: Orthogonal in Chapel

- This is a **parallel**, but local program:

```
begin writeln("Hello world!");
writeln("Goodbye!");
```

- This is a **distributed**, but serial program:

```
writeln("Hello from locale 0!");
on Locales[1] do writeln("Hello from locale 1!");
writeln("Goodbye from locale 0!");
```

Parallelism and Locality: Orthogonal in Chapel

- This is a **parallel**, but local program:

```
begin writeln("Hello world!");
writeln("Goodbye!");
```

- This is a **distributed**, but serial program:

```
writeln("Hello from locale 0!");
on Locales[1] do writeln("Hello from locale 1!");
writeln("Goodbye from locale 0!");
```

- This is a **distributed**, **parallel** program:

```
begin on Locales[1] do writeln("Hello from locale 1!");
on Locales[2] do begin writeln("Hello from locale 2!");
writeln("Goodbye from locale 0!");
```

Outline

- ✓ Chapel Motivation and Background
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Chapel's Origins: HPCS

DARPA HPCS: High Productivity Computing Systems

- **Goal:** improve productivity by a factor of 10x
- **Timeframe:** Summer 2002 – Fall 2012
- Cray developed a new system architecture, network, software stack…
  - this became the very successful Cray XC30™ Supercomputer Series

…and a new programming language: Chapel

Chapel under HPCS: Major Successes

Clean, general parallel language design

- unified data-, task-, concurrent-, nested-parallelism
- distinct concepts for parallelism and locality
- multiresolution language design philosophy

SSCA#2 demonstration on the prototype Cray XC30

- unstructured graph compact application
- clean separation of computation from data structure choices
- fine-grain latency-hiding runtime
- use of Cray XC30™ network AMOs via Chapel's 'atomic' types
- ran on full-scale demo system for significant amount of time

Portable design and implementation

- while still being able to take advantage of Cray-specific features

Revitalization of Community Interest in Parallel Languages

- HPF-disenchantment became interest, cautious optimism, enthusiasm

Chapel under HPCS: Shortcomings

Performance was hit-or-miss (and mostly "miss" at scale)

- a litmus test for the HPC community

Focused on a narrow set of benchmarks (mostly SSCA#2)

- several key idioms and language features were neglected

Contract milestones were set too far in advance

- unable to respond effectively to needs of real users
- changes required contract renegotiations

Insufficient focus on emerging node architectures

- unable to effectively leverage NUMA nodes, GPUs

Didn't get over the tipping point of adoption

- but, we got far enough to make it to the next level…

Chapel's 5-year push

- **Based on positive user response to Chapel under HPCS, Cray undertook a five-year effort to improve it**
  - we've just completed our second year
- **Focus Areas:**
  1. Improving **performance** and scaling
  2. **Fixing** immature aspects of the language and implementation
     - e.g., strings, memory management, error handling, …
  3. **Porting** to emerging architectures
     - Intel Xeon Phi, accelerators, heterogeneous processors and memories, …
  4. Improving **interoperability**
  5. Growing the Chapel user and developer **community**
     - including non-scientific computing communities
  6. Exploring transition of Chapel **governance** to a neutral, external body

The Chapel Team at Cray

Chapel is a Collaborative, Community Effort

(and many others as well, some of which you will hear from today…)

http://chapel.cray.com/collaborations.html

A Year in the Life of Chapel

- **Two major releases per year** (April / October)
  - **~a month later:** detailed release notes
- **SC** (Nov)
  - annual **Lightning Talks BoF** featuring talks from the community
  - annual **CHUG happy hour**
  - plus tutorials, panels, BoFs, posters, educator sessions, exhibits, …
- **CHIUW:** Chapel Implementers and Users Workshop (May/June)
  - kicked off May 2014 at IPDPS
- **Talks, tutorials, research visits, blogs, …** (year-round)

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Suggested Reading

Overview Papers:

- *A Brief Overview of Chapel*, Chamberlain (early draft of a chapter for *A Brief Overview of Parallel Programming Models*, edited by Pavan Balaji, to be published by MIT Press in 2015).
  - *a detailed overview of Chapel's history, motivating themes, features*

- *The State of the Chapel Union* [slides], Chamberlain, Choi, Dumler, Hildebrandt, Iten, Litvinov, Titus. CUG 2013, May 2013.
  - *a higher-level overview of the project, summarizing the HPCS period*

Lighter Reading

Blog Articles:

- *Chapel: Productive Parallel Programming*, Cray Blog, May 2013.
  - *a short-and-sweet introduction to Chapel*

- *Why Chapel?* (part 1, part 2, part 3), Cray Blog, June-October 2014.
  - *a recent series of articles answering common questions about why we are pursuing Chapel in spite of the inherent challenges*

- *[Ten] Myths About Scalable Programming Languages*, IEEE TCSC Blog (index available on chapel.cray.com "blog articles" page), April-November 2012.
  - *a series of technical opinion pieces designed to combat standard arguments against the development of high-level parallel languages*

Online Resources

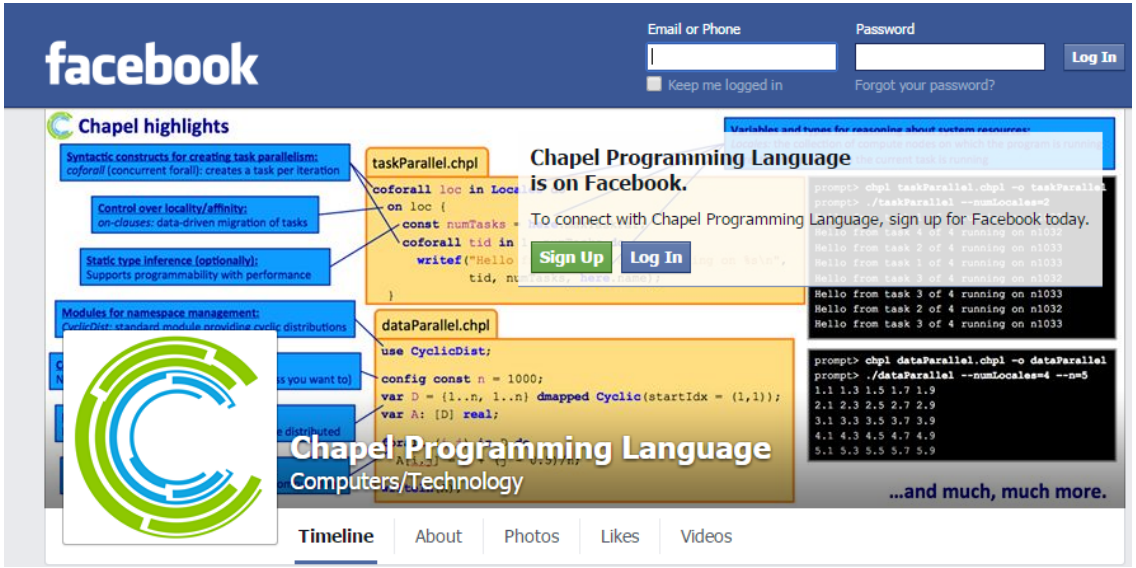
Project page: http://chapel.cray.com

- overview, papers, presentations, language spec, …

GitHub page: https://github.com/chapel-lang

- download Chapel; browse source repository; contribute code

Facebook page: https://www.facebook.com/ChapelLanguage



Community Resources

SourceForge page: https://sourceforge.net/projects/chapel/

- hosts community mailing lists
  (also serves as an alternate release download site to GitHub)

Mailing Aliases:

- chapel_info@cray.com: contact the team at Cray
- chapel-announce@lists.sourceforge.net: read-only announcement list
- chapel-users@lists.sourceforge.net: user-oriented discussion list
- chapel-developers@lists.sourceforge.net: developer discussion
- chapel-education@lists.sourceforge.net: educator discussion
- chapel-bugs@lists.sourceforge.net: public bug forum

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