State of the Chapel Project 2016

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Chapel Team, Cray Inc.
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A Year in the Life of Chapel

- **Two major releases per year** (April / October)
  - ~a month later: detailed release notes available online

- **CHIUW:** Chapel Implementers and Users Workshop (May/June)

- **SC** (Nov)
  - tutorials, BoFs, panels, posters, educator sessions, exhibits, …
  - annual **CHUG** (Chapel Users Group) happy hour
  - For SC16: Hope to re-establish the **Chapel Lightning Talks BoF**
    - concept: propose 4 (CHIUW?) talks at submission time, 2 wildcards

- **Talks, tutorials, collaborations, social media, …** (year-round)
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Chapel Releases since CHIWW 2015
Releases since CHIUW 2015

- Since last year, two new versions of Chapel released:
  - 1.12: October 1, 2015
  - 1.13: April 7, 2016

- Significant progress in all areas
  - language, library, docs, performance, memory, portability, bugs, ...

- ~3500 downloads in past year for prior two releases:
Contributors to the Past Year’s Releases

Contributors to 1.12 / 1.13:

- Ben Albrecht, Cray Inc.
- Ian Bertolacci, Cray Inc. / Colorado State University
- Kyle Brady, Cray Inc.
- Paul Cassella, Cray Inc.
- Brad Chamberlain, Cray Inc.
- Sung-Eun Choi, Cray Inc.
- Lydia Duncan, Cray Inc.
- Michael Ferguson, Cray Inc.
- Ben Harshbarger, Cray Inc.
- Tom Hildebrandt, Cray Inc.
- David Iten, Cray Inc.
- Przemysław Leśniak, individual contributor
- Vassily Litvinov, Cray Inc.
- Tom MacDonald, Cray Inc.
- Cory McCartan, Cray Inc.
- Damian McGuckin, Pacific Engineering Systems International
- Phil Nelson, Western Washington University / Cray Inc.
- Michael Noakes, Cray Inc.
- Joshua Olson, individual contributor
- Konstantina Panagiotopoulou, individual contributor
- Nicholas Park, DOD
- Elliot Ronaghan, Cray Inc.
- Kushal Singh, individual contributor
- George Stelle, Sandia National Laboratories
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- Tony Wallace, Cray Inc.

17 Cray employees, 2 Cray interns, 10 external contributors
The Chapel Team at Cray (May 2016)

14 full-time employees + 2 summer interns
(one of each started after photo taken)
Chapel Community R&D Efforts

(and several others, some of whom you will hear from today…)

http://chapel.cray.com/collaborations.html
Key Language Improvements (1.12 & 1.13)

- **Memory Consistency Model**: specification greatly improved
- **Namespace control**: public/private, filtered module ‘use’s’ (see Lydia Duncan’s talk this afternoon)
- **Memory management of records**: huge improvements
- **Strings**: vastly improved
  - simplified implementation
  - virtually leak-free (a long-term pain-point for users)
  - significant performance improvements
  - standard library of operations
String Improvements: Leaks / Performance

New string implementation was enabled on December 9th

In our test suite...

...string-related memory leaks went from 123MB to 22MB
  ● by 1.13, down to ~300B

...# of tests with leaks reduced by 2.6x

...fasta-lines version of CLBG benchmark sped up 2.7x
  ● another version improved 20%
String Improvements: Standard Library

String routines:

this() // substring
these() // iterate over chars
startsWith()
endsWith()
find()
rfind()
count()
replace()
split()
join()
strip()
partition()
localize()
c_str()
isEmptyString()
isUpper()
isLower()
isSpace()
isAlpha()
isDigit()
isAlnum()
isPrintable()
isTitle()
toLower()
toUpper()
toTitle()
capitalize() +, +=, *, ==, !=, <=, ...
Other Key Library Improvements (1.12 & 1.13)

● Notable new modules:
  Spawn: subprocess control
  Barrier: barrier synchronization
  Reflection: meta-programming capabilities
  PCGRandom: PCG-based random number generation
  LAPACK, LinearAlgebraJAMA: linear algebra packages

● Notably improved modules:
  Random: supports extended interface and PCG-based algorithms
  FileSystem: now complete
Key Documentation Improvements (1.12 & 1.13)

CHIUW 2015: Online docs had just been launched
  ● strong positive response from users

CHIUW 2016: Docs significantly expanded (125+ pages):
  ● README-based files from release
  ● standard distributions / layouts
  ● “built-in” types / functions
  ● ‘chpl’ and ‘chpldoc’ man pages
  ● started writing a Chapel users guide

...also significantly reorganized for clarity
(see following slides or http://chapel.cray.com/docs/latest/)
Online Docs landing page (version 1.11)

chpldoc documentation

Contents:

- Module: AdvancedIters
- Module: Assert
- Module: BitOps
- Module: Buffers
- Module: CommDiagnostics
- Module: Curl
- Module: Error
- Module: FFTW
- Module: FFTW_MT
- Module: FileSystem
- Module: GMP
- Module: HDFS
- Module: HDFSIterator
- Module: Help
- Module: IO
- Module: List
- Module: Math
- Module: Memory
- Module: Norm
- Module: Path
- Module: Random
- Module: RecordParser
- Module: Regexp
- Module: Search
Online Docs landing page (version 1.13)

Chapel Documentation

Compiling and Running Chapel

- Quickstart Instructions
- Using Chapel
- Platform-Specific Notes
- Technical Notes
- Tools

Writing Chapel Programs

- Quick Reference
- Language Specification
- Built-in Types and Functions
- Standard Modules
- Package Modules
- Standard Layouts and Distributions
- Chapel Users Guide (WIP)

Language History

- Chapel Evolution

Index

- Chapel Online Documentation Index
Key Performance Optimizations (1.12 & 1.13)

- **Compiler improvements:**
  - locality and communication optimizations
  - initial support for vectorization
  - enabled competitive performance from LLVM back-end

- **Runtime improvements:**
  - Qthreads-based tasking now used by default
  - jemalloc-based memory now used by default
  - ‘ugni’-based improvements for Cray networks
Stream EP Performance (versions 1.9–1.12)

Stream EP Performance Across Chapel Releases

(128 nodes)

GB/s per node

Chapel version (six-months per release)

v1.9  v1.10  v1.11  v1.12

MPI+OpenMP

Chapel
STREAM Scaling (1.11 vs. 1.12, EP vs. global)

Stream performance more than doubled from 1.11 to 1.12
- EP is on par with the reference
- Global is also very competitive
RA (atomics) Scaling (1.12 vs. 1.13, qthreads vs. muxed)

RA perf (atomics version) improved from 1.12 to 1.13
- ugni+qthreads performance improved 5x
- ugni+muxed performance improved 3x
RA (rm0) Scaling (1.12 vs. 1.13, qthreads vs. muxed)

RA (remote memory ops version) also improved for 1.13
- 3x better performance for both ugni+qthreads and ugni+muxed
Scaling of ‘reduce’ (1.12 vs. 1.13, qthreads vs. muxed)

- Reductions improved dramatically from 1.12 to 1.13
  - improved parallel efficiency/scalability
  - significantly improved raw performance

![Efficiency of Reductions Graph](image-url)
Other Key Improvements (1.12 & 1.13)

- **Tools:**
  - *chplvis:* visualize comm/tasking (see Phil Nelson’s talk this afternoon)

- **Benchmarks:**
  - *ISx:* Integer Sort proxy app (see Ben Harshbarger’s talk this morning)
  - *LCALS:* Loop Kernels proxy app (see David Iten’s talk this morning)

- **Portability:**
  - *NUMA nodes:* significant locality improvements
  - *Intel® Xeon Phi™:* initial support (formerly “Knight’s Landing” / “KNL”)

- **Design Efforts:**
  - initializers (constructor redesign)
  - error-handling
  - *CHIPs:* Chapel Improvement Proposals
    - see: [https://github.com/chapel-lang/chapel/blob/master/doc/chips/1.rst](https://github.com/chapel-lang/chapel/blob/master/doc/chips/1.rst)
Next Steps: Top Ten Priorities for 1.14

1. Close all remaining memory leaks and lock into testing
2. Finalize and implement initializers and copy semantics
3. Multi-locale performance improvements
4. NUMA/KNL locale models and performance (including HBM support)
5. Sparse / associative array improvements (distributed, performance)
6. Data analytics case studies
7. Single-locale performance improvements
8. Implement error-handling
9. Add comm/comp overlap for ‘qthreads’ (and retire ‘muxed’?)
10. Improve support for first-class functions / closures
Chapel in the Community
The CLBG recently started accepting Chapel entries

- Compares execution time, source size, memory, ... x 13 benchmarks
- [http://benchmarksgame.alioth.debian.org/](http://benchmarksgame.alioth.debian.org/)

Waiting until we’ve submitted more benchmarks before adding Chapel to front page
Chapel CLBG: entries to date

● Trying to review and submit 1–3 benchmarks per week

● Four entries submitted so far:
  ● pidigits, n-body, mandelbrot, thread-ring

● Striving for a combination of elegance and performance
  ● more heroic versions possible, but we’re avoiding for first drafts
    ● e.g., manually unrolling mandelbrot => 40% performance improvement
Chapel CLBG: how are we doing?

Noting that easy answers are often incomplete or wrong...

...we have three #1 entries so far: one for performance, two for size

Interesting to compare execution times of similarly compact (non-heroic?) versions
CLBG: Next Steps

● Complete initial round of submissions

● Tackle opportunities for improvement…
  …without losing sight of scalability / distributed memory goals
  …prioritizing ones that would benefit end-users of the language
  (don’t want to optimize simply for CLBG’s sake)
Chapel’s Google Summer of Code (GSoC)

- Applied to be a GSoC 2016 organization
  - Compiled a project ideas list and developed new web content: [http://chapel.cray.com/gsoc](http://chapel.cray.com/gsoc)
  - Were one of 178 accepted organizations from a pool of 369
GSoC 2016: Submissions

● Once announced, saw a sharp uptick in Chapel activity
  ● #chapel-developers chatroom; mailing lists; GitHub repos, forks, PRs
  ● 3 GSoC applicants listed among contributors to version 1.13

● 46 student applications received
  ● granted 2 student slots from Google
  ● would have liked to have taken many more if we’d been able

● Some of the proposed projects:
  ● Stack-trace reporting on halts (accepted)
  ● Incremental recompilation (accepted)
  ● Online compiler for Chapel
  ● Chapel GUI library
  ● Begin expressions
  ● STL-like data structures and algorithms
  ● Build a web server in Chapel
Chapel Blog Posts since CHIUW 2015

Chapel Springs into a Summer of Code, April 2016
- highlighted 1.13 release, GSoC, CHIUW program, new Twitter feed

Six Ways to Say “Hello” in Chapel (parts 1, 2, 3), Sept-Oct 2015
- overview of data- and task-parallel hello worlds for single-/multi-locale

Chapel Users `CHIUW' Their Way Through Portland, June 2015
- overview of CHIUW 2015
Chapel Book Chapter Published

Chapel chapter in *Programming Models for Parallel Computing*

- a detailed overview of Chapel’s history, motivating themes, features
- chapter is now also available [online](#)
Chapel added to GitHub PL Showcase (Nov 2015)

Programming languages
A list of programming languages that are actively developed on GitHub.
35 repositories  29 languages  Last updated 15 days ago

Apple/swift
The Swift Programming Language

Rust-lang/rust
A safe, concurrent, practical language.

golang/go
The Go programming language

dart-lang/sdk
The Dart SDK, including the VM, dart2js, core libraries, and more.

chapel-lang/chapel
A Productive Parallel Programming Language

dylan-lang/opendylan
Open Dylan compiler and IDE

currently #32/35
Held Wednesday Oct 14, 2016 as an all-day session
- Cray Chapel team drafted and edited answers
- followed up on straggling questions over the following two days
Chapel AMA on /r/ProgrammingLanguages

- Thread received 58 comments + 34 responses overall
  - 24 unique user IDs, 19 of whom posted top-level questions

- Received a net score of 26 points, 75% upvoted
  - currently #2 in top links from the past year
Chapel at PGAS15 (Washington DC, Sept 16-18)

**Productive Programming in Chapel: A Computation-Driven Introduction**, tutorial, Brad Chamberlain and Michael Ferguson, Sept 16
- 3-hour tutorial with 2 hands-on sessions
- dry-run of SC15 tutorial
- ~12 attendees (though some familiar faces in audience, some here today)

**Five Things You Should Do to Create a Future-Proof Exascale Language**, invited talk, Brad Chamberlain, Washington DC, Sept 17
- 45-minute talk
- call-to-arms for PGAS language designers and why Chapel’s on-track
- ~30-35 attendees, primarily PGAS students and researchers (same for following talks)

**Caching Puts and Gets in a PGAS Language Runtime**, research paper and talk, Michael Ferguson, Sept 17
- 30-minute talk
- description of compiler optimization to cache fine-grained communication

**Toward a Data-Centric Profiler for PGAS Applications [poster]**, research poster and talk, Hui Zhang (University of Maryland), Sept 17
- research poster and short talk
- analysis to tie execution time to data structures rather than control structures
Notable “Learning Chapel” Artifacts

Learn Chapel in Y Minutes, http://learnxinyminutes.com, Ian Bertolacci
- dense one-file overview of Chapel

Chapel By Example: Image Processing, manual, Greg Kreider, Primordial Machine Vision Systems
Summary

● Chapel is thriving
  ● significant improvements with each release
    ● capabilities and performance
  ● strong core team at Cray—largest and most capable ever
  ● continued growth in the community and in outward-facing forums

● CHIUW is a crucial part of Chapel’s growth
  ● thanks to today’s speakers and audience members for participating
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