

Library Improvements

Chapel Team, Cray Inc.

Chapel version 1.16

October 5, 2017





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Outline

- **New Modules**

- Cryptography
- TOML
- Parallel Collections
- Distributed Dynamic Iterators

- **Module Improvements**

- ZMQ
- LinearAlgebra
- MPI Interoperability
- C Interoperability Improvements
- Other Library Improvements



New Modules



COMPUTE | STORE | ANALYZE

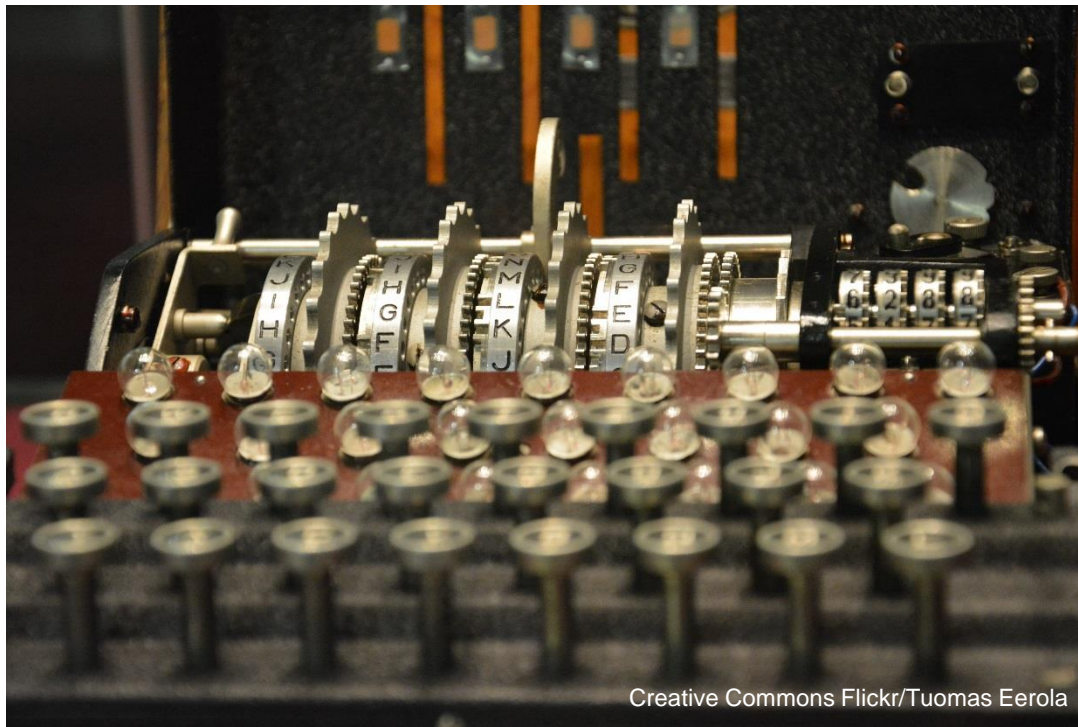
Cryptography

Contributed by Sarthak Munshi as a GSoC project



Cryptography: Background

- Chapel had no built-in support for cryptography
- Desirable to natively encrypt/decrypt/hash





Cryptography: This Effort

- **Implemented a new Cryptography module**
 - Built on top of a new wrapper for the OpenSSL library
 - Includes several cryptography tools
 - Symmetric Ciphers (AES)
 - Asymmetric Ciphers (RSA)
 - Hashing functions (MD5, SHA, RIPEMD)
 - Key Derivation Functions (PBKDF2)
 - Cryptographically secure random number generator (CryptoRandom)

- **Google Summer of Code Project**



Cryptography: Impact

- Much OpenSSL functionality is now available in Chapel

```

use Crypto;
config const message = "secret message";

const aes = new AES(256, "cbc"),
        msg = new CryptoBuffer(message);
        // Also define salt, IV, hash, key

const ct = aes.encrypt(msg, key, IV);
        plaintext = aes.decrypt(ct, key, IV);

writeln("original: ", toString(msg));
writeln("encrypted: ", toString(ct));
writeln("decrypted: ", toString(plaintext));

```



```

original: secret message
encrypted: ��$%??U!#E^~?
decrypted: secret message

```




Cryptography: Status & Next Steps

Status: Cryptography module is now available

- Routines to encrypt and decrypt
- Secure hash functions
- Secure pseudo-random number generation

Next Steps: Add extra functionality from OpenSSL

- Additional cipher algorithms
 - ECC, DES, Blowfish, Twofish
- Additional key derivation functions
- Consider switching from classes to records / 'Owned' classes
 - goal: avoid need for 'delete'



TOML





TOML

Background: TOML is a popular markup language

- "Tom's Obvious, Minimal Language"
- TOML was chosen as the language for mason's manifest & lock files
 - So Chapel needed a TOML reader/writer module

This Effort: Created a TOML module

- Example Usage:

```
use TOML;
```

```
var TomlFile = open("Mason.toml", iomode.r);
```

```
// Parses TOML file into Toml data structure – also accepts channel or string
```

```
var TomlData = parseToml(TomlFile);
```

```
var version = TomlData["version"].toString(); // Reads a value
```

```
TomlData["version"] = "2.0.1"; // Writes a value
```

```
writeln(TomlData); // Writes to stdout in TOML format
```

```
delete TomlData; // Clean up
```





TOML

Status: Chapel has a TOML module

- Mason uses this module to read and write manifest & lock files
- Majority of TOML spec implemented
- Undocumented due to a desire to modify interface

Next Steps: Complete TOML module implementation

- Finish implementing TOML specification
 - Notably, arrays of tables
- Finalize interface design and add to public documentation
- Avoid explicit memory management through use of Owned module



Parallel Collections

Contributed by Louis Jenkins as a GSoC project



Parallel Collections

Background: A goal is to support any parallel algorithm

- And in particular to support global view programming
- One common global-view idiom: a work queue
 - for distributing work among existing tasks
- Chapel supports work queues for tasks themselves, but
 - those work queues are local only
 - the work queues can only contain tasks, not other work items



Parallel Collections: This Effort

- **3 new package modules support the work queue idiom:**

- Collections – describes interface; asserts:
 - Data structure is parallel-safe
 - Data structure supports insertion, removal, and iteration

- DistributedBag – "work queue" with relaxed ordering

```
var c = new DistBag(int, targetLocales=Locales);  
for i in 1..10 do c.add(i); // order not preserved  
var counter: atomic int;  
forall elem in c do counter.add(elem);
```

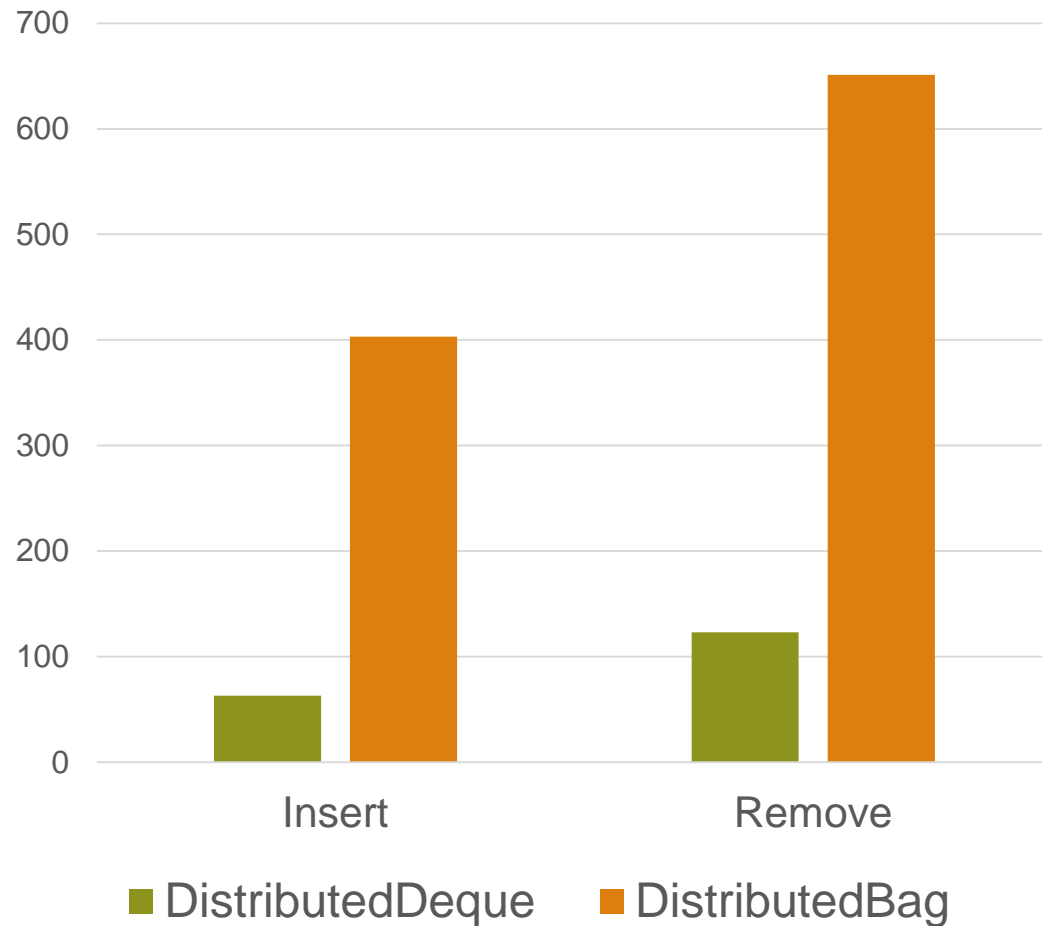
- DistributedDeque – parallel FIFO/LIFO queue

```
var c = new DistDeque(int, targetLocales=Locales);  
for i in 1..10 do c.add(i); // order preserved  
var counter: atomic int;  
forall elem in c do counter.add(elem);
```



Parallel Collections: Performance

x faster than 'locked list' on 64 nodes



```
coforall loc in Locales do
  on loc do
    coforall t in 0..#nTasks do
      for i in 1..n do
        c.add(i);
```

```
coforall loc in Locales do
  on loc do
    coforall t in 0..#nTasks do
      for i in 1..n do
        c.remove();
```


Parallel Collections

Impact: Significantly more performant work queue available

- Especially with multiple locales
- Even on 1 locale, DistributedBag is faster than locked list

Next Steps:

- Use in a real application
- Improve documentation
- Continue related effort of supporting distributed atomic class instances

Distributed Dynamic Iterators





Dist. Dynamic Iterators: Background

- **Dynamicters module provides OpenMP-style scheduling**
 - Dynamic, guided, and adaptive iterators
 - These work with both ranges and domains

- **No distributed load-balancing iterators available**
 - Users had to resort to writing their own iterators





Dist. Dynamic Iterators: This Effort

- **Created distributed iterators based on dynamic, guided**
 - Implemented in 'DistributedIters' package module
 - Can also be zipped with things that can follow ranges and domains
 - Can iterate over ranges and domains

```
use DistributedIters;
```

```
forall i in distributedDynamic(1..n) do  
    imbalancedWorkload(i);
```

- **Users can optionally specify worker locales**

- Default is all locales

```
const halfLocales = Locales[1..numLocales/2];
```

```
forall i in distributedGuided(1..n,  
                               workerLocales=halfLocales) do  
  
    work(i);
```



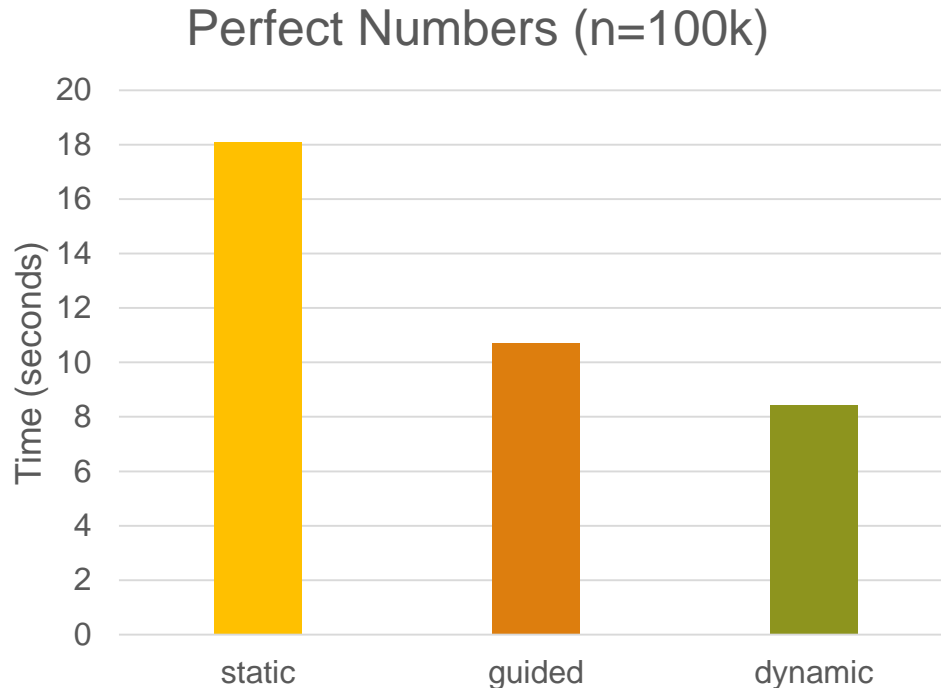
Dist. Dynamic Iterators: This Effort

- **Optionally enable/disable coordination mode**
 - 'coordinated: bool' - if true, first worker only distributes work
 - Locking/atomics often refer back to first worker
 - Can improve performance when network atomics are unavailable
- **Optionally provide chunk sizes**
 - Controls how much work each task/locale receives
 - Still looking for good defaults
 - See documentation for argument names
 - <http://chapel.cray.com/docs/1.16/modules/packages/DistributedItrs.html>



Dist. Dynamic Iterators: Impact

- **Options now exist for distributed load-balancing**
 - e.g., find perfect numbers in uniform random distribution from 1..n
 - Implemented as naive $O(n)$ algorithm



- ugni-qthreads on 16 nodes of Cray XC30



Dist. Dynamic Iterators: Status and Next Steps

Status:

- 'DistributedIters' included as package module in 1.16

Next Steps:

- Performance tuning
 - Finding good default chunk sizes
 - Study in real-world workloads
- Support arrays in addition to domains and ranges



Module Improvements



ZMQ





Background: ZMQ was not 100% cross-language compatible

- Serialization of records was not compatible with REQ/REP socket
 - This caused incompatibility with other language bindings (e.g. PyZMQ)

This Effort: Reimplemented send/recv for records in ZMQ

- Confirmed this works for sending strings to PyZMQ with new tests
- Contributed by Nicholas S. Park

Impact: ZMQ enables cross-language communication

Status: ZMQ module is compatible with PyZMQ

- Functionality tested nightly



Linear Algebra





LinearAlgebra

Background: LinearAlgebra added in 1.15

- Supported dense linear algebra operations and helper functions
- Did not support sparse linear algebra
 - Sparse linear algebra has many important applications, like graph analytics
 - User-requested feature
- Few introductory examples
 - Common request from users

This Effort: Improved LinearAlgebra module

- Added 'Sparse' submodule with documentation
- Added a LinearAlgebra primer
 - Includes sparse examples
- Other minor improvements



LinearAlgebra: Sparse submodule

- **Subset of linear algebra features for dense matrices**

- Uses the same interface and naming schemes

```

use LayoutCS;
use LinearAlgebra.Sparse;

var D = CSRDomain(5, 5); // empty 5x5 sparse domain
var A = CSRMatrix(D); // sparse array over 'D'
D += [(1,1), (2,2), (4,3), (3,4)]; // Add indices to domain
A = 4.0; // Set all nonzeros

var B = A.dot(A);
for i in B.domain do writeln(i, ": ", B[i]);
// (1, 1): 16.0
// (2, 2): 16.0
// (4, 3): 16.0
// (3, 4): 16.0

```





LinearAlgebra: Added Primer

Chapel Documentation 1.16

Search docs

COMPILING AND RUNNING CHAPEL

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

WRITING CHAPEL PROGRAMS

- Quick Reference
- Hello World Variants

Primers

- Language Basics
- Iterators
- Task Parallelism
- Locality
- Data Parallelism
- Library Utilities

Numerical Libraries

- LinearAlgebra**
 - Compiling
 - Basics
 - Factory Functions
 - Operations
 - Properties

Docs » Primers » LinearAlgebra [View page source](#)

LinearAlgebra

[View LinearAlgebra.lib.chpl on GitHub](#)

Example usage of the `LinearAlgebra` module in Chapel.

Table of Contents

- LinearAlgebra
 - Compiling
 - Basics
 - Linear Algebra Types
 - Array operations
 - Factory Functions
 - Vectors
 - Matrices
 - Operations
 - Properties
 - Structure
 - Caveats
 - LinearAlgebra.Sparse
 - Supported Sparse Layouts
 - Factory Functions
 - Operations

```
use LinearAlgebra;
```

Compiling





LinearAlgebra: Other Improvements

- **Documentation corrected for triangular functions**
- **diag() function contributed by Prabhanjan Mannari**
 - Extracts diagonal from matrices into a vector
 - Builds a diagonal matrix from a vector
- **Adopted array.op(arg) interface for all matrix operations:**
 - A.plus(B)
 - A.minus(B)
 - A.times(B)
 - A.elementDiv(B)
 - A.dot(B)
- **Deprecated matPlus and matMinus**
 - array.op(arg) style preferred



Linear Algebra

Status: Sparse linear algebra and primer added in 1.16

Next Steps: Additional Linear Algebra features

- Distributed Linear Algebra
 - Dense
 - Sparse
- LAPACK support
 - Eigensolvers, SVDs, etc.
- Linear Algebra on GPUs
 - CuBLAS, cIBLAS
- Improve compilation process
 - Add build option for Chapel to download BLAS and LAPACK

MPI Interoperability





MPI Interoperability: Background and Effort

Background: Could not use Qthreads with MPI

- Non-preemptive tasks could cause deadlock

This Effort: Permit using MPI with Qthreads

- Implemented blocking operations with non-blocking op + yielding-wait

```
proc Send(...) {  
    MPI_Isend(...);  
    MPI_Test(flag, ...);  
    while flag == 0 {  
        chpl_task_yield();  
        MPI_Test(flag, ...);  
    }  
}
```

Impact: Can now use MPI and Qthreads

- Improved performance for user's nbody simulation



C Interoperability Improvements



Interoperability Improvements

- Added 'isAnyCPtr()' and 'isExternClassType()' queries
- 'c_memcpy'/'c_memmove' allow 'c_void_ptr' arguments
- Added 'c_sizeof()' and 'c_memset()'
- 'writeln' can now print 'c_ptr' and 'c_void_ptr' variables
 - contributed by Nick Park



Other Library Improvements



Other Library Improvements

- **Renamed 'Barrier' module to 'Barriers'**
 - To avoid having the 'Barrier' type share the same name as its module
- **Removed deprecated 'RandomStream' constructors**
- **Added waitAll() to 'Futures' module**
- **Added param/type overloads of getField() routines**
- **Added channel.lines() to iterate over lines in a channel**
- **Added file.getParentName() to 'Path' module**





Other Library Improvements

- Added `datetime.ctime()` to 'DateTime' module
- Added `asciiToString()` function
- Squashed entries with 0 as output from comm diagnostics





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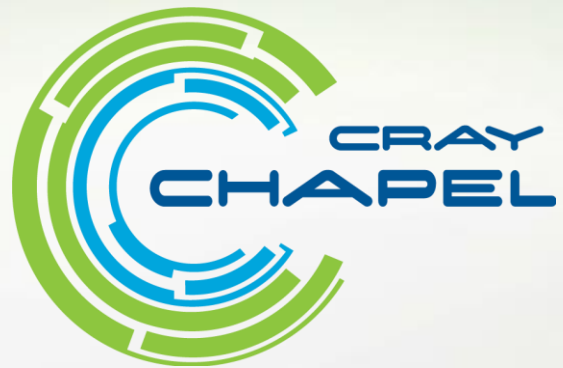
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