Library Improvements

Chapel Team, Cray Inc.
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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
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

```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: ��$%��Uђ#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’
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:

```toml
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
```
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
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

```c
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();
```

![Bar chart showing performance comparison between DistributedDeque and DistributedBag](image)
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

- **DynamicIters 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/DistributedIters.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

Perfect Numbers (n=100k)

- ugni-qthreads on 16 nodes of Cray XC30
Dist. Dynamic Iterators: Status and Next Steps

Status:
- ‘DistributedIterators’ 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
LinearAlgebra
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 nonzeroes

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

LinearAlgebra

View LinearAlgebraLib.chpl on GitHub

Example usage of the LinearAlgebra module in Chapel.

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  - LinearAlgebra.Sparse
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    - Factory Functions
    - Operations

```chapel
use LinearAlgebra;
```

Compiling
Linear Algebra: 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, clBLAS
- 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
  
```c
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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