Library Improvements

Chapel Team, Cray Inc.

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Outline

- **Standard Module Improvements**
  - Math
  - Path
  - DateTime
- **Package Module Improvements**
  - Crypto
  - LinearAlgebra
- **Other Library Improvements**

Standard Module Improvements

Math

Math

Background: Bessel functions were not supported

- Bessel functions are available in C standard library
- Requested by several Chapel users

This Effort: Implement Bessel functions available in standard C

- Includes *nth* order first kind (*j*) and second kind (*y*) Bessel functions
- Supports real(64) and real(32)
- Contributed by Nimit Bhardwaj

Status: Bessel functions now supported in Math module

```
j0(100);      // First kind, 0th order
j1(100);      // First kind, 1st order
jn(100, 9);   // First kind, nth order
y0(10);       // Second kind, 0th order
y1(10);       // Second kind, 1st order
yn(10, 5);    // Second kind, nth order
```

Path

Path

Background:

- Intended to contain 15 routines modeled after Python's os.path library
  - Proposed during 1.11 release cycle, prior to good string support
- As of last release, 9 routines left unimplemented

This Effort:

- Added support for joinPath(), isAbsPath(), and commonPath()
- Contributed by Surya Priy, Unnati Parekh, Prithvi Patel

Status:

- Path module now only missing 6 routines
- Windows paths not supported
  - (Chapel does not support Windows natively at present)

Next steps:

- Implement remaining features

DateTime

DateTime

Background: DateTime objects leaked timezones, lacked IO

- If the timezone field was used, it was not deleted
- Reading/writing DateTime objects used default record IO

This Effort: Fixed leak and improved I/O format

- Convert the timezone field into a Shared object
  - It is now reclaimed automatically
- Added IO routines to the DateTime types
  - Dates and times are read/written in ISO format

```
2018-03-29T14:41:37.747151
```

Impact:

- Timezone memory is handled automatically
- Output format for dates and times is significantly improved

Package Module Improvements

Crypto

Crypto

Background: The Blowfish Cipher is available in OpenSSL

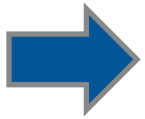
- But there was no Chapel interface to it

This Effort: Add Blowfish class to the Crypto package

- New class can encrypt/decrypt data using the Blowfish algorithm
- Contributed by Sarthak Munshi

Impact: Blowfish cipher can be used from Chapel programs

```
use Crypto;
const msg = new CryptoBuffer("secret”),
      bf = new Blowfish("cbc");
const ct = bf.encrypt(msg, key, iv),
      pt = bf.decrypt(ct, key, iv);
writeln("encrypted: ", toString(ct));
writeln("decrypted: ", toString(pt));
```



```
encrypted: □□□[2□0□
decrypted: secret
```

* Definitions of key, iv, and toString() are omitted for space

Next steps: Provide more functionality from OpenSSL

- ECC, DES, Twofish, additional key derivation functions, …

LinearAlgebra

LinearAlgebra: Background

- **Provides a high-level interface for linear algebra**
  - Design influenced by NumPy and MatLab
  - Provides helper functions for creating matrices and vectors as arrays
  - Supports many linear algebra operations on matrices and vectors
- **Implementations use both Chapel and BLAS library**
  - e.g. matrix-matrix multiplication uses BLAS
- **'Sparse' submodule supports sparse linear algebra**
  - Supports a subset of the features available in Linear Algebra module

LinearAlgebra: This Effort

- **Improved Performance**
  - Faster sparse matrix-matrix multiplication implemented
- **New Features**
  - Added Cholesky decomposition and eigensolvers
    - Using LAPACK
  - Added Kronecker product
    - Contributed by Nimit Bhardwaj
  - Added support for sparse identity matrices
    - Contributed by Nikhil Padmanabahn
- **Interface Changes**
  - Switched to 1-based indices as default instead of 0-based indices
  - New dependency on LAPACK library in addition to BLAS

LinearAlgebra: Impact

- **LinearAlgebra library contains more features:**

```
use LinearAlgebra, Random;

var A = Matrix(10, 10);
fillRandom(A);
// Eigenvalues
var eig = eigvals(A);
// Eigenvalues and eigenvectors
var (eig, right) = eigvals(A, right=true);
// Eigenvalues, eigenvectors, and left eigenvectors
var (eig, left, right) = eigvals(A, left=true, right=true);
// Obtain L & U with Cholesky decomposition
var L = cholesky(A);
var U = cholesky(A, lower=false);
// Compute Kronecker Product
var kronProduct = kron(A, A);
```

LinearAlgebra: Impact

- **LinearAlgebra module consistent with Chapel indices**

```
// Fewer surprises in user interface
var array = [1,2,3];
var vector = Vector(1,2,3);
assert(array.domain == vector.domain); // {1..3}
```

- **Sparse matrix-matrix multiplication is faster**
  - New algorithm performs better as density approaches 0
  - Measured performance of squaring NxN sparse matrix:

```
var AA = dot(A, A); // A is 2D CSR array
```

nonzero elements	density	1.16 (seconds)	1.17 (seconds)
1e4	0.01%	**1.9e-2**	**4.5e-5**
1e7	1e-8%	**38.75**	**0.02**

LinearAlgebra: Next Steps

- **Progress tracked in issue #5753**
- **Performance Improvements**
  - Enable non-sorted indices in CS layout for sparse matrix multiplication
  - Parallelize sparse matrix multiplication
- **Support other computation models**
  - Distributed array support
  - GPU support, using CuBLAS/CuLAPACK
- **More dense and sparse features**
- **Address promotion flattening issue, #5958**

Other Library Improvements

Other Library Improvements

- added channel.advancePastByte() to read until particular byte
- added versions of channel.mark(), commit(), revert() for locking==false
- array push* methods now use in intents and now support Owned
- added string.size overload for string.length
- made the Buffers module into a package module
- made UtilReplicatedVar module into package module ReplicatedVar
- added a new scalable barrier across all locales
- added binaryInsertionSort to the Sort module
- updated several modules to use error handling rather than try! / halt()
- added --debugTomlReader flag for TOML.TomlReader submodule

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