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
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 $n$th 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
**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

```chapel
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));
```

* 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

<table>
<thead>
<tr>
<th>nonzero elements</th>
<th>density</th>
<th>1.16 (seconds)</th>
<th>1.17 (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1e4</td>
<td>0.01%</td>
<td>1.9e-2</td>
<td>4.5e-5</td>
</tr>
<tr>
<td>1e7</td>
<td>1e-8%</td>
<td>38.75</td>
<td>0.02</td>
</tr>
</tbody>
</table>
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
- `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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