Standard Library Improvements

Chapel Team, Cray Inc.
Chapel version 1.12
October 1st, 2015
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Outline

- ‘Barrier’ module: Task Barrier Synchronization
- ‘LAPACK’ Standard Module
- ‘Spawn’ module: Spawning Subprocesses
- Vectorizing Iterator
- New Math Constants in the Math module
- Other Standard Library Improvements
‘Barrier’ module: Task Barrier Synchronization
Task Barrier: Background

- All tasks must complete first step before moving on
Task Barrier: This Effort

● Provide a task barrier type
  ● Prevent $k$ tasks from continuing until all have notified the barrier
  ● Implemented as a class in the Chapel standard library

● Choose implementation details in constructor call
  ● e.g., two underlying counter representations
    ● Atomic-based task count (the default)
      ```chapel
      var b_atomic = new Barrier(nTasks);  // atomic task counter
      ```
    ● Sync-based task count
      ```chapel
      var b_sync = new Barrier(nTasks, BarrierType.Sync);  // sync counter
      ```

● Single-phase or split-phase, based on methods called

  Single-phase
  ```chapel
  b.barrier();
  ```

  Split-phase
  ```chapel
  b.notify();
  if b.try() then ...
  b.wait();
  ```
Task Barrier: Single-Phase Example

- All tasks must reach the barrier before any can pass it
  - All “entering the barrier” messages print.
  - Then all “past the barrier” messages print.

```plaintext
use Barrier;

config const numTasks = here.maxTaskPar;
var b = new Barrier(numTasks);

coforall tid in 1..numTasks {
    writeln("Task ", tid, " entering the barrier");
    b.barrier();
    writeln("Task ", tid, " past the barrier");
}
delete b;
```
Task Barrier: Split-Phase Example

- Tasks can do background work after notifying the barrier

```javascript
use Barrier;

config const numTasks = here.maxTaskPar;
var b = new Barrier(numTasks);

coforall tid in 1..numTasks {
    updateSharedState();
    b.notify();
    doBackgroundWork();
    b.wait();
    readSharedState();
}
delete b;
```
Task Barrier: Distributed Example

- Barriers can synchronize tasks spanning multiple locales

```plaintext
use Barrier;
var b = new Barrier(numLocales);

coforall locid in 0..#numLocales {
  on Locales[locid] {
    writeln("Hello from locale ", here.id);
    b.barrier();
    writeln("Goodbye from locale ", here.id);
  }
}
delete b;
```
Task Barrier: Status and Next Steps

Status:

- Barrier class type functionally correct for...
  - Atomic- or sync-based counters
  - Single- or split-phase usage
  - Single- or multi-locale scenarios
- Documentation at:
  - [http://chapel.cray.com/docs/1.12/modules/standard/Barrier.html](http://chapel.cray.com/docs/1.12/modules/standard/Barrier.html)

Next Steps:

- Switch to record type for automatic memory management
  - waiting on fixes to memory management for records
  - this will remove the need to delete barrier objects as in current use
- Optimize the implementation of barriers
  - particularly for the multi-locale case
- Create “task-teams” concept, and implement barriers for them
‘LAPACK’ Standard Module
LAPACK: Background and This Effort

Background:

- Users are increasingly interested in numerical libraries out of the box
  - e.g., FFTW, BLAS, GSL, LAPACK, etc.
- Chapel support has historically been thin
- Belief that Chapel features should result in nice interfaces
  - particularly domains/arrays and generics
LAPACK: Background and This Effort

This Effort:

- Developed by Ian Bertolacci (summer intern, Colorado State Univ.)
- Adds support for (most) LAPACK routines in two forms:
  - Idiomatic Chapel interface
  - Classic interface
- Requires users to have their own LAPACK installation
- LAPACK module generated automatically by scraping sources/docs
  - virtually necessary due to the large size of the API
- Documented online:
- Primer example available in examples/ directory
LAPACK: Impact

Example using idiomatic Chapel interface:
- Uses information stored in Chapel’s arrays
- Benefits from Chapel’s support for generic functions

```chapel
use LAPACK, Random;

// Solve for X in A*X = B
var A : [1..5, 1..5] real;
var B : [1..5, 1..3] real;
var ipiv : [1..N] c_int; // output array of pivot indices

fillRandom(A);
fillRandom(B);

var WorkA = A; // LAPACK will use array data as a workspace, so
var WorkBX = B; // make copies to preserve the original data
var err = gesv(lapack_memory_order.row_major, WorkA, ipiv, WorkBX);

if err == 0 then writeln("X = ", WorkBX);
```
Comparing idiomatic vs. classic interfaces:

// idiomatic interface
var err = gesv(lapack_memory_order.row_major, WorkA, ipiv, WorkBX);

// classic interface
var err = LAPACKE_sgesv(lapack_memory_order.row_major,
WorkA.domain.dim(1).size:c_int,
WorkB.domain.dim(2).size:c_int,
WorkA,
WorkA.domain.dim(2).size:c_int,
ipiv, WorkBX,
WorkB.domain.dim(2).size:c_int);
LAPACK: Next Steps

● **Get user feedback**
  ● Does the Chapel interface make sense? Could it be better?
  ● Does the classic interface add value?

● **Fix a few known gaps stemming from C interoperability**
  ● Move away from using c_int’s in Chapel idiomatic interfaces
  ● Improve support for using C99 complex types
  ● Support passing of Chapel functions to externs
  ● Better handling of enums

● **Investigate ways to test/validate module**
  ● Thousands of functions!
LAPACK: Next Steps

● Improve support for row- vs. column-major order
  ● Add flags to domain maps to support either layout
  ● Have idiomatic routines query this information from arrays

● Explore post-LAPACK linear algebra support
  ● ‘LAPACK’ module is exactly that – a module wrapping LAPACK
  ● Many users simply want “linear algebra”
    ● would a different backing library be preferable?
      ● e.g., one that is parallel and/or distributed?
      ● e.g., Eigen, Trilinos, PetSc, Elemental/FLAME, PLASMA/MAGMA, …
    ● support a common L.A. library with multiple backing implementations?

● Continue adding support for other numerical libraries
  ● BLAS and subsets of GSL are next priorities
‘Spawn’ module: Spawning Subprocesses
Spawn Module: Background

- Want Chapel to be useful for multi-program composition
  - would like it to be viable as a parallel scripting language
  - e.g., for all files in this directory, compress them with `gzip`

- Chapel did not support spawning other processes directly
  - was possible through the extern interface, but awkward
Spawn Module: This Effort

- Add a new ‘Spawn’ standard module
  - inspired by Python's Subprocess module
  - input and output are available for redirection
  - C runtime supports this with `posix_spawn`

```javascript
use Spawn;

// create a subprocess running md5sum
var sub = spawn(['md5sum', filename], stdout=PIPE);

// consume each line from the spawned md5sum process
var line:string;
while sub.stdout.readline(line) {
    write("md5sum returned: ", line);
}

// perform any remaining communication and wait for process to exit
sub.communicate();
```
Spawn Module: Impact

● **Enhances Chapel's ability to compose multiple programs**
  ● Improves support for parallel scripting workflows
  ● Supports multi-language integration in a coarse-grained manner
  ● Enables program re-use

● **Used to improve a Twitter processing benchmark**
  ● Benchmark wanted to read *gzip* compressed files
    ● Previously, were unzipping the files manually…
    ● This was our motivation for implementing the Spawn module
    ● Now the program spawns *gzip* commands to read the files
Spawn Module: Status and Next Steps

Status:

● Spawn feature implemented and documented
  http://chapel.cray.com/docs/1.12/modules/standard/Spawn.html

● Problems with CHPL_COMM=ugni when redirecting input or output
  ● Observed seg faults from clone() system call
  ● Added halt() for a better error message for this known issue
  ● CHPL_COMM=gasnet with aries conduit works

Next Steps:

● Improve support for CHPL_COMM=ugni
● Add other ways of providing input and output:
  ● file path
  ● a Chapel file
  ● a Chapel channel
● Fill in other missing functionality
  ● continue to draw on Python's Subprocess for inspiration
● Get feedback from users
Vectorizing Iterator
Vectorizing Iterator: Background

- **Vectorization is crucial for achieving peak performance**
  - True for commodity and HPC systems
  - Becoming increasingly important, particularly in HPC
    - AVX-512 (Xeon and Xeon Phi)
    - NEON (ARM)

- **Previous releases focused on “implicit” vectorization**
  - Generating idioms the back-end can better auto-vectorize
  - Emitting hints to the back-end for vectorizable Chapel constructs
    - i.e. foralls, promoted expressions, etc
  - However, no way vectorize without also creating tasks
    - desirable for loops with small trip counts
Vectorizing Iterator: This Effort

- **Provide a simple way to vectorize without task creation**
  - Implemented as a “wrapper” iterator
  - e.g. to vectorize range iteration:
    ```
    for i in 1..10 {...}  =>  for i in vectorizeOnly(1..10) {...}
    ```

- **Asserts order-independence and disables task creation**
  - i.e. same result when invoked with a serial or data parallel-loop
  for example:
    ```
    forall i in vectorizeOnly(1..10) {...}
    for i in vectorizeOnly(1..10) {...}
    ```
    both effectively generate:
    ```
    #pragma ivdep
    for (i=0; i<=10; i+=1) {...}
    ```
Vectorizing Iterator: This Effort

- **Automatically handles zippering to vectorize:**

  ```python
  for (a, b) in zip(A, B) {...}
  ```

  simply write:

  ```python
  for (a, b) in vectorizeOnly(A, B) {...}
  ```
Vectorizing Iterator: Status and Next Steps

Status:
- vectorizeOnly() iterator implemented
  - has significant correctness testing
  - further performance evaluation is required

Next Steps:
- Evaluate performance impact of vectorizeOnly() using LCALS
- vectorizeOnly() clean-up:
  - move into a standard module (will not be implicitly included)
  - improve orthogonality with zippering
  - consider generating warning for serial (for-loop) invocations
- Create a vectorization primer as a guide for:
  - implicit vectorization
  - vectorizeOnly() iterator
New Math Constants in the Math module
Math Constants Added to the Math module

**Background:** Math.chpl was missing constants for \(\pi\), \(e\), etc
- These are in C's `math.h`, but were omitted from Chapel's Math.chpl

**This Effort:** Adds math constants found in C's `math.h`

```chapel
param \(\pi = 3.14159\)

\(\pi\) - the circumference/the diameter of a circle

param \(\text{half}\_\pi = 1.5708\)

\(\pi/2\)
```

**Next Steps:** Consider compile-time param real evaluation
- Constants like `half\_\pi` might not be necessary
- Could/should compiler evaluate `param real` expressions like `\(\pi/2\)` ?
Other Standard Library Improvements
Other Standard Library Improvements

- renamed memory diagnostics symbols for clarity
- **improved format() routine**
  - changed from standalone function to string.format()
  - unified format strings with writef()
- **in format strings, “##.##” now requires curly brackets**
  - old scheme led to challenges, e.g. when wanting to print ‘#’ characters
- added getFileSize() to ‘FileSystem’ module
- ‘UtilMath’ module merged into ‘Math’
- errorToString() now portably returns ‘No Error’
- applied ‘private’ to standard module symbols that are
  - a few cases remain due to tests that refer to them, needing rewriting
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