Standard Library Improvements

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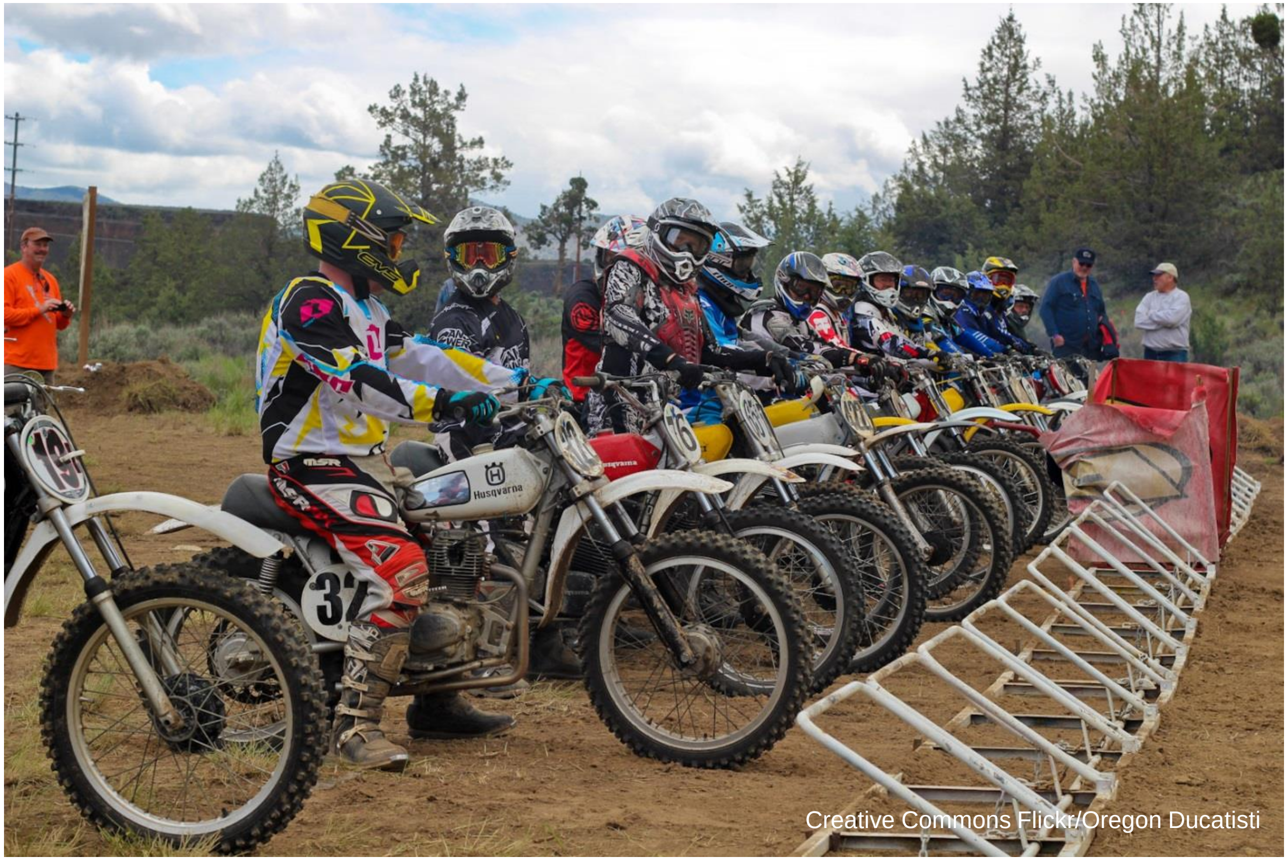
Outline

- ‘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



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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)

      ```
      var b_atomic = new Barrier(nTasks);    // atomic task counter
      ```
    - Sync-based task count

      ```
      var b_sync = new Barrier(nTasks, BarrierType.Sync); // sync counter
      ```

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

Single-phase

```
b.barrier();
```

Split-phase

```
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.

```
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 barrer

```
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

```
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

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:
  http://chapel.cray.com/docs/1.12/modules/standard/LAPACK.html
- Primer example available in examples/ directory
  https://github.com/chapel-lang/chapel/blob/master/test/release/examples/primers/LAPACKlib.chpl

LAPACK: Impact

Example using idiomatic Chapel interface:

- Uses information stored in Chapel's arrays
- Benefits from Chapel's support for generic functions

```
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);
```

LAPACK: Impact

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);
```

Array element type embedded in routine name

Need to pass in array sizes explicitly

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`

```
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:

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

  simply write:

  ```
  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

param `pi` = 3.14159

pi - the circumference/the diameter of a circle

param `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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