Compiler and Tool Improvements

Chapel version 1.20
September 19, 2019

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Outline

- Creating and Using Libraries
- Mason Improvements
- LLVM Back-end Improvements
Creating and Using Chapel Libraries
Chapel Libraries: Background

• Have had a draft capability to create Chapel libraries
  • ‘--library’ flag generates library instead of executable
    • ‘main()’ function not valid in this compilation mode

• Supported single-locale libraries for C, Python, and Fortran
  • But not multi-locale libraries
• Supported primitive types and arrays (some natively, some opaquely)

• Much work remained
Multi-locale Libraries
Multi-locale Libraries: Background

• Had support for single-locale libraries and multi-locale executables
  • But not multi-locale libraries

• Chapel expects to control how a program is distributed
  • Trickier when Chapel doesn’t own ‘main()’

• By last release, had determined strategy for support but not yet implemented it
Multi-locale Libraries: This Effort

• Added multi-locale ‘--library’ support
  • Like non-library multi-locale, users don’t have to worry about launching
    • Agnostic to user program running on compute or login node
  • Similar behavior for routine calls, argument types, etc. to single-locale

• Requires ZMQ installation
Multilokale Libraries: Example Program

// foo.chpl

export proc hello() {
    coforall loc in Locales do on loc {
        writeln("Hello from locale ", loc);
    }
}

// use_foo.py

import foo

// specify number of locales

foo.chpl_setup(2)
foo.hello()
foo.chpl_cleanup()

$ chpl --library-python --comm=gasnet foo.chpl
$ export PYTHONPATH=lib/
$ python3 use_foo.py

Hello from locale 1
Hello from locale 0
Typical Multi-Locale Compilation + Execution

myChplProg.chpl → chpl --comm=… → myChplProg

Login node

myChplProg_real
Typical Multi-Locale Compilation + Execution

The user executes this

myChplProg.chpl

chpl --comm=…

myChplProg

myChplProg_real

Login node
myChplProg.chpl → chpl --comm=… → myChplProg → myChplProg_real

Login node

Which launches this onto the various locales
Typical Multi-Locale Compilation + Execution

myChplProg.chpl → chpl --comm=… → myChplProg → myChplProg_real

Login node

Locale 0
Locale 1
Locale 2
Locale n
Typical Multi-Locale Compilation + Execution

myChplProg.chpl → chpl --comm=… → myChplProg

Login node

myChplProg_real

Locale 0

myChplProg_real

Locale 1

myChplProg_real

Locale 2

myChplProg_real

Locale n
Multi-Locale Chapel-Python Interop
Multi-Locale Chapel-Python Interop

The user writes and executes this:

```
chpl --library-python
```

Login node

```
myChplProg.chpl
chpl --library-python
myChplProg.so
myChplProg_real
```
Multi-Locale Chapel-Python Interop

```sh
myChplProg.chpl
```

```sh
chpl --library-python
```

```sh
myChplProg.so
```

```sh
myChplProg_real
```

Which calls into this

Login node
Multi-Locale Chapel-Python Interop

Which launches this onto the various locales
Multi-Locale Chapel-Python Interop

myChplProg.chpl → chpl --library-python → myChplProg.so → myChplProg_real → Login node

Locale 0
Locale 1
Locale 2
Locale n
Multi-Locale Chapel-Python Interop

myChplProg.chpl

chpl --library-python

myChplProg.so

myChplProg_real

Locale 0

Locale 1

Locale 2

... Locale n
Multi-locale Libraries: This Effort

• Library initialization now requires specifying the number of locales
  • In multi-locale with Python, ‘chpl_setup()’ now takes an argument
    
    \begin{verbatim}
    chpl_setup(); // call to set up library for single-locale Python (unchanged)
    chpl_setup(numLocs); // call for multi-locale Python (new arg!)
    \end{verbatim}

• With C, pass ‘-nl <num>’ in addition to other arguments to ‘chpl_library_init()’
  
  \begin{verbatim}
  // One strategy for multi-locale C:
  int argChapelC = 3;
  char* argChapelV[3] = {argv[0], "-nl", "2"};
  chpl_library_init(argChapelC, argChapelV);
  \end{verbatim}
Multi-locale Libraries: Status

• Supports most primitive types and Chapel strings
  • Strings only support ‘[const] in’ intent due to copying contents
  • Doesn’t support ‘complex’ or arrays yet

• Supports Python and C
  • Doesn’t support Fortran just yet
  • Doesn’t support LLVM back-end
String Support: Background

• Exported Chapel routines did not support exporting the ‘string’ type at all:
  • Instead, users had to use ‘c_string’

    // Wouldn’t work, strings can’t be in exported routine declarations
    export proc foo(s: string): string {
      return s + "", yo";
    }

• This presented some problems:
  • Strings are a fundamental type
    • e.g., Arkouda’s RPC protocol is implemented in terms of strings
  • We want to deprecate support for ‘c_string’, not put more weight on it
String Support: This Effort

• We added support for exporting strings to C and Python
• When exporting to C, a Chapel routine’s formal arguments map to ‘c_string’
  • Returned strings map to ‘char*’

```chapel
export proc useful(in s: string): string { ... }

/* Making use of this routine in C... */
char* msg = useful("hello");
printf("%s\n", msg);
chpl_free(msg);
```

• When exporting to Python, Chapel strings map to the Python ‘bytes’ type
String Support: Supported Intents

• Single- and multi-locale libraries support different formal argument intents
• In multi-locale and Python libraries:
  • ‘string’ arguments must have the ‘in’ intent
  • strings may only be returned by value

```haskell
export proc foo(in s: string): string;
```

• Restrictions on argument intents exist for multi-locale libraries by design
  • Arguments are copied when they are communicated to the multi-locale library
• For single-locale Python, these restrictions may be temporary
String Support: Impact, Next Steps

**Impact:**
- Strings can now be passed between Chapel and client languages

**Next Steps:**
- Support more formal argument intents in both single- and multi-locale libraries
- Support returning by ref intent in single-locale libraries
- Use Python ‘string’ rather than ‘bytes’ to interoperate with Chapel ‘string’
- Support the Chapel ‘bytes’ type
- Minimize copying via compiler support
Libraries and LLVM
Background: ‘--library --llvm’ created libraries usable from C programs

• This mode was unable to create libraries for Python
• Several ‘--library-*’ flags were not supported

This Effort: Extended support to include:

• ‘--dynamic’, enabling the creation of shared libraries
• ‘--library-python’, enabling Python interoperability
• ‘--library-makefile’, generating Makefile to make compiling with the lib easier
• ‘CHPL_LIB_PIC’, enabling position independent code
Chapel Libraries: Impact and Next Steps
Chapel Libraries: Impact

• Multi-locale and Chapel string support make interoperability stronger

• Chapel can now support user scenarios like Arkouda’s
  • Almost all of Arkouda can be compiled as a multi-locale library
    • Remaining issues relate to null bytes embedded in strings
    • Support for ‘bytes’ arguments in exported routines should help
Chapel Libraries: Next Steps (short-term)

• Support other intents for string formals in exported routines
  • For single-locale libraries, we want to support all intents in the future
  • For multi-locale libraries, we want extend support to include ‘inout’

• Support passing ‘bytes’ between Python and Chapel
  • This should permit all of Arkouda to be compiled as a multi-locale library
Chapel Libraries: Next Steps (medium-term)

- Extensions for LLVM compiler back-end
  - Support multi-locale and Fortran libraries with LLVM
    - multi-locale libraries need adjustments to their build process for LLVM
    - Fix ABI incompatibility when returning arrays
- Support exporting a wider variety of types and symbols
- More robust default values for Python
Chapel Libraries: Next Steps (longer-term)

• Enable users to link against multiple Chapel libraries
• Enable Chapel libraries to be used by Chapel programs
• Adopt a long-term serialization strategy and RPC protocol for multi-local libraries
  • Currently, the compiler generates serialization code
  • Our RPC protocol is simple and blocking
  • Protobuf and Google RPC are viable alternatives
• Extend interoperation to other languages
  • C++ interoperability has been requested
• Support libraries built with ‘--no-local’ and ‘CHPL_LAUNCHER != none’
  • Using similar strategy to multilocal libraries
Mason Improvements
Mason: Background

• Mason is a package manager for Chapel programs
  • Introduced with Chapel 1.16.0
• Mason is still under development and has some known shortcomings:
  • Preventing web queries requires throwing ‘--no-update’ with most commands
    • This can become tedious when working in an offline environment
  • Publishing mason packages requires many manual steps
    • This increases the barriers for users to publishing their packages
  • The mason test system is very simple, only based on exit code
    • This puts a lot of work on the user and lacks flexibility
Mason: This Effort - Using Mason Offline

• New ‘MASON_OFFLINE’ environment variable indicates user is working offline
  • Sets ‘--no-update’ flag by default for relevant mason commands
    • Can be overridden by throwing ‘--update’
  • Disables usage of ‘mason external’ commands that require internet access
    • Specifically, commands that install Spack or Spack packages
  • Does not prohibit accessing local registries on the filesystem
Mason: This Effort - Mason Publish

- New ‘mason publish’ command helps users publish packages
  
  `mason publish [options] <registry>`

- Automates creation of version tag, changes to registry, and pushing to remote

- Supports local and remote registries, defaulting to chapel-lang/mason-registry

- Some prerequisites still remain for remote registries:
  - User must host package on a remote git repository
  - User must fork registry to which they are publishing

- Supports flags to help guide users:
  - ‘--dry-run’ flag checks if general package prerequisites are met
  - ‘--check’ flag checks if prerequisites are met for a specific registry
Mason: This Effort - Mason Publish Example

> mason publish
...
remote: https://github.com/ChapelUser/mason-registry/pull/new/Foo
remote:
To github.com:ChapelUser/mason-registry
  * [new branch]       Foo -> Foo

Go to the above link to open up a Pull Request to the mason-registry

> mason publish /path/to/local/registry
Successfully published package to /path/to/local/registry
Mason: This Effort - Mason Test

- ‘mason test’ serves as the test runner for the new UnitTest module
  - As a result, ‘mason test’ can be used outside of a mason package
    ```
mason test [options] <path>
    ```
- ‘mason test’ remains backwards-compatible with exit-code-based testing
  - If UnitTest module not used, entire file is considered a single test
    - Exit code of 0 is required for pass
- Mason packages can contain a mix of exit-code and UnitTest tests
Mason: Status, Next Steps

**Status:**
- Offline experience for mason improved
- Publishing mason packages to registries is easier
- Mason packages can now include tests written with the new UnitTest module

**Next Steps:**
- Continue improving mason:
  - CI testing of mason-registry
  - Centralized package cache
  - Package security
Improvements to the LLVM Back-end
LLVM: Background

- LLVM is a compiler optimization framework
  - Actively developed and constantly improving
- The Chapel compiler generates C code by default
  - Runs a C compiler to compile the generated code
  - But can generate LLVM Intermediate Representation instead
- We want the Chapel compiler to use LLVM by default
  - To reduce maintenance
    - supporting a variety of C compilers requires significant effort
  - To enable new optimization opportunities
LLVM: This Effort

• Upgraded the bundled LLVM to version 8 and fixed a variety of bugs
• A Google Summer of Code project made improvements to --llvm:
  
<table>
<thead>
<tr>
<th>Student</th>
<th>Mentors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mohammed Nafees</td>
<td>Michael Ferguson</td>
</tr>
<tr>
<td></td>
<td>Przemek Leśniak</td>
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</tbody>
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• The generated llvm.ident now includes Chapel version information
  • llvm.ident identifies the compiler that generated the LLVM IR
• Stopped generating C in most cases when using --llvm
• Emit llvm.lifetime.start / llvm.lifetime.end metadata to aid optimization
• Improved --llvm -g debug information generation
LLVM: Next Steps

• Implement full ABI compatibility
• Make --llvm the default for the 1.21 release
• Study more benchmarks to try and improve performance
• Continue to work on Region Vectorizer integration
  • Mark more loops as vectorizable
• Improve alias analysis between C and Chapel types
• Improve debugging experience with --llvm -g
For More Information

For a more complete list of compiler and tools changes in the 1.20 release, refer to 'New Tools / Tool Changes', 'Interoperability Improvements', 'Portability', 'Compiler Improvements', and other sections in the CHANGES.md file.
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