Compiler and Tool Changes

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Outline

- LLVM Improvements
- Specifying Target Architecture
- Disambiguating Param Configs
- Retiring chpl-ipe
LLVM Improvements
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 vs. depending on many C compilers
  • To enable new optimization opportunities
Chapel --llvm compilation flow

```
a.chpl  b.chpl  ...
```

```
chpl
```

```
a.c  b.c
```

```
Chapel runtime (.h, .a)
```

```
CC
```

```
Executable
```
Chapel --llvm compilation flow

```plaintext
runtime .h extern { }

a.chpl
b.chpl
```

```
clang
chpl
```

```
LLVM module
```

```
LLVM Opts
```

```
linker
```

```
Executable
```

```
runtime .a
```

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LLVM: PRK Stencil Improvement

- PRK stencil had poor multi-locale performance with --llvm
- Optimization was limited by alias analysis between C and Chapel types
- Migrated a privatization function from the C runtime to Chapel
  - Long-term, would like to improve alias analysis

PRK-Stencil Performance

![Graph showing performance comparison between C Backend and LLVM Backend]

- GFlops/s
- C Backend
- LLVM Backend
LLVM: Upgrade to LLVM 7

- Upgraded the included LLVM from LLVM 6 to LLVM 7
- Provided close to 10% improvement for LCALS 'couple' kernel
LLVM: Enhanced compatibility

- The LLVM back-end can now link statically
- Now compatible with LLVM versions 6-8
- Now compatible with MacOS Mojave
- Removed ‘register’ keyword from Qthreads (deprecated in C++)
  - Our change was merged upstream
  - Enabled '--llvm' to work on 32-bit x86
- Improved ability to find header files in more diverse installations
- Improved ability to invoke the optimizer on Cray XC systems
LLVM: Floating point optimization

- Configured LLVM optimization to use fused floating-point multiply-add by default
- Resulted in a modest performance improvement for two benchmarks
LLVM: no-alias hints

- Added new analysis pass to determine when Chapel arrays cannot alias
- Used the result to communicate to LLVM IR when array dereferences don't alias
  - via ‘noalias’ metadata
- Provided close to 2x performance improvement for some benchmarks
LLVM: Vectorization

- LLVM includes a parallel_loop_access loop metadata hint
  - Indicating to optimization no memory carried dependencies
- LLVM's LoopVectorizer is pretty good at adding runtime checks
  - To verify that aliasing doesn't introduce memory dependencies
- Now chpl emits parallel_loop_access metadata for forall and vectorizeOnly loops
  - But only when we are confident vectorization is safe
  - Can improve performance when the cost of the runtime check is significant
- Investigated prototype integration with the Region Vectorizer
  - A more general vectorizer than the LLVM Loop Vectorizer
  - Shows promising speedups for some benchmarks
LLVM: Next Steps

• Implement full ABI compatibility
• Make --llvm the default for the 1.20 release
• Study more benchmarks to try and improve performance
• Continue to work on Region Vectorizer integration
  • Mark more loops as vectorizeable
• Improve alias analysis between C and Chapel types
Choosing the Target Architecture and CPU for Specialization
target cpu: Background

• Before 1.19, there was no way to specify machine type
  • CHPL_TARGET_PLATFORM indicated an OS, e.g. linux64
  • CHPL_TARGET_ARCH specified a processor type, e.g. sandybridge
• In fact CHPL_TARGET_ARCH was used to determine 3 things:
  • A processor architecture, e.g. x86_64
  • A processor implementation, e.g. sandybridge
  • A symbolic processor type for specialization/optimization, e.g. native
• Led to problems when one chapel directory is used for incompatible architectures
  • CHPL_TARGET_ARCH=native used same paths for both
  • Compiler build and bin directory did not differentiate at all
target cpu: This Effort

• Split CHPL_TARGET_ARCH into two flags
  • CHPL_TARGET_ARCH now means processor architecture
    • For example x86_64, arm, aarch64, ppc64
  • CHPL_TARGET_CPU now means CPU type for specialization
    • For example sandybridge, k8, native, none, sandybridge

• Added CHPL_HOST_ARCH, used it in compiler paths
  • Compiler is in bin/$CHPL_HOST_PLATFORM-$CHPL_HOST_ARCH
    • For example bin/linux64-x86_64/chpl

• Updated build and third-party install paths
target cpu: Impact

• Now possible to work with different architectures when
  • Building Chapel from source from a shared directory
  • Installing Chapel to a shared directory
  • Including when using CHPL_TARGET_CPU=native
Compile-time Config Disambiguation
Config Disambiguation: Background

Background:

• Distinct modules may happen to use the same config names

```plaintext
module M1 { config const debug = false; ... }
module M2 { config const debug = true; ... }
```

• Chapel has long supported execution-time disambiguation of configs:

```plaintext
$ ./myProg --M1.debug=true --M2.debug=false
```

• However, compile-time configs have not received similar support

```plaintext
$ chpl myProg.chpl -sdebug=true
myProg.chpl:2: error: Ambiguous config param or type name ...
$ chpl myProg.chpl -sM1.debug=true
error: Trying to set unrecognized config param 'M1.debug' ...
```
Config Disambiguation: This Effort and Impact

This Effort:

• Added disambiguation support for compile-time configs
• Improved error messages when ambiguity occurs

Impact: Compile-time disambiguation now works much better:

```bash
$ chpl myProg.chpl -sdebug=true
myProg.chpl:2: error: ambiguous config name (debug)
myProg.chpl:1: note: also defined here
myProg.chpl:2: note: (disambiguate using -s<modulename>.debug...)
$ chpl myProg.chpl -sM1.debug=true
$ ./myProg
```
Config Disambiguation: Next Steps

Next Steps:

• Extend disambiguation to support module paths
• Currently only supports disambiguation of top-level module configs

```chapel
module M1 {
    module M2 {
        config const debug = false;
    }
}
```

```
$ chpl -sM1.M2.debug=true myProg.chpl
$ ./myProg --M1.M2.debug=true
```
Retiring chpl-ipe
chpl-ipe: Background and This Effort

Background:

• ‘chpl-ipe’ provided a prototype interactive Chapel environment
  • Added in Chapel 1.11.0
  • A proof-of-concept that supported minimal Chapel features
  • Took the approach of incrementally parsing code, interpreting the IR
  • Has received little attention or upkeep since then
• Main takeaway: interactive Chapel warrants a different compilation approach
• Meanwhile, we were carrying around the code, documentation, issues, …

This Effort: Removed chpl-ipe from the release to clear the slate
chpl-ipe: Status and Next Steps

Status:

• Still want to support Chapel in an interactive mode
• Have some proposals for how that could be achieved
  • Though they tend to require dramatic changes to the compiler
  • Such changes would likely help with other things too (e.g., compile time)

Next Steps:

• Determine the right timing and resources to pursue this
• Decide upon and prototype a new approach
For More Information

For a more complete list of compiler and tools changes in the 1.19 release, refer to 'Feature Improvements', 'Compiler Improvements', 'Performance Optimizations/Improvements', 'Portability', 'Packaging / Configuration Changes', 'Deprecated and Removed Features, and other sections in the CHANGES.md file.
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