Compiler / Implementation

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Outline

- LLVM Back-end Improvements
- Partially Generic Resolution Changes
- Iterator Inlining Improvements
- Dynamic Cast Optimization
- Other Compiler Improvements
- Error message improvements
- Bug Fixes

LLVM Back-end Improvements

LLVM: Background

- **We'd like to use LLVM more with Chapel…**

  …but have not been able to do so yet due to:
  - performance problems
  - insufficient testing

- **What is LLVM?**
  - Open source, modular, reusable compiler technologies

- **How does Chapel work with LLVM?**
  - Since 1.6, one can build Chapel with CHPL_LLVM=llvm
  - Then, the --llvm compilation flag activates the LLVM back-end
  - --llvm is an alternative to generating C and running a C compiler

LLVM: Background

- **Why do we want to work more with the LLVM back-end?**
  - only have to wrestle with portability/performance of a single back-end
    - instead of multiple versions of various C compilers
  - possible to create Chapel-specific low-level optimizations
  - Chapel compiler can choose which low-level optimizations run
  - possibility to migrate some Chapel optimizations to LLVM
    - LLVM is a strong, documented framework
    - more compiler developers are proficient with LLVM than with Chapel AST

LLVM: This Effort

- **Prepare LLVM back-end for production use**
  - Testing improvements
    - Nightly testing now includes full --llvm testing instead of small subset
  - Performance improvements
    - Upgraded from LLVM 3.7 to 4.0
    - Google Summer of Code improvements
  - Developer-focused changes
    - Chapel sources are ready to build with LLVM 5
    - New command-line option --mllvm to set LLVM optimization flags
    - Perform more LLVM optimizations in 'chpl' rather than at link-time

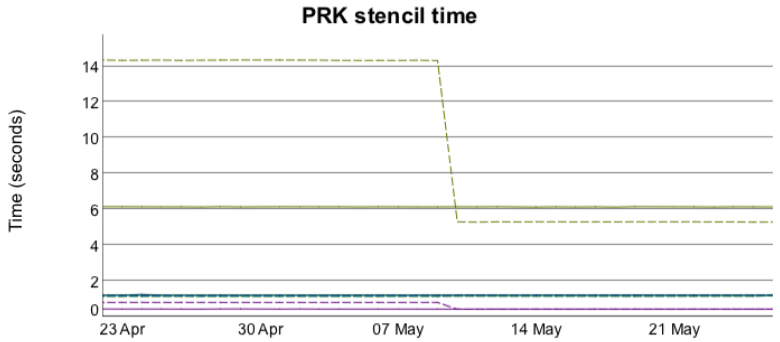
LLVM: Google Summer of Code

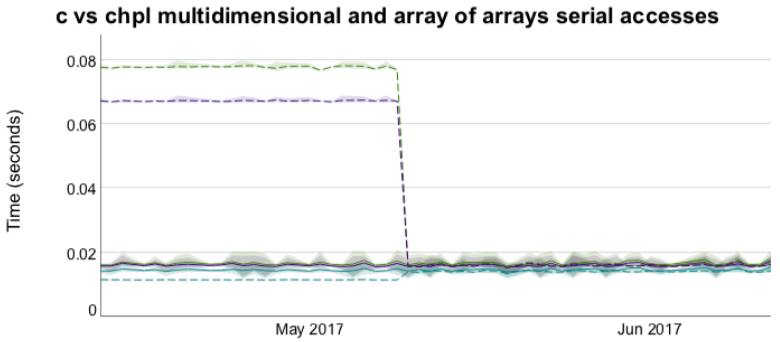
LLVM GSoC: This Effort

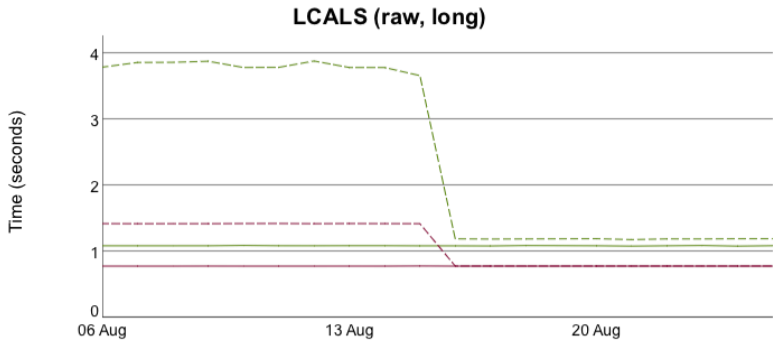
- **Przemysław Leśniak contributed many improvements:**
  - mark signed integer arithmetic with 'nsw' to improve loop optimization
  - command-line flags to emit LLVM IR at particular points in compilation
  - new tests that use LLVM tool FileCheck to verify emitted LLVM IR
  - mark order-independent loops with llvm.parallel_loop_access metadata
  - mark const variables with llvm.invariant.start
  - enable LLVM floating point optimization when --no-ieee-float is used
  - add nonnull attribute to ref arguments to functions
  - use clang built-ins to improve performance of arithmetic on complex numbers

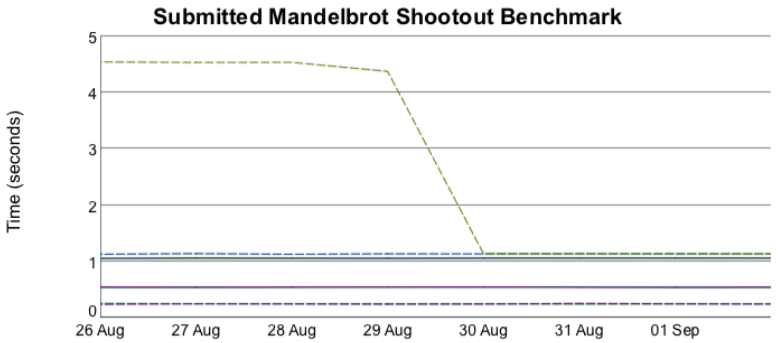
LLVM GSoC: Impact

- **Performance improvements for a variety of benchmarks**
  - Notably, many array-focused benchmarks now on par with C back-end







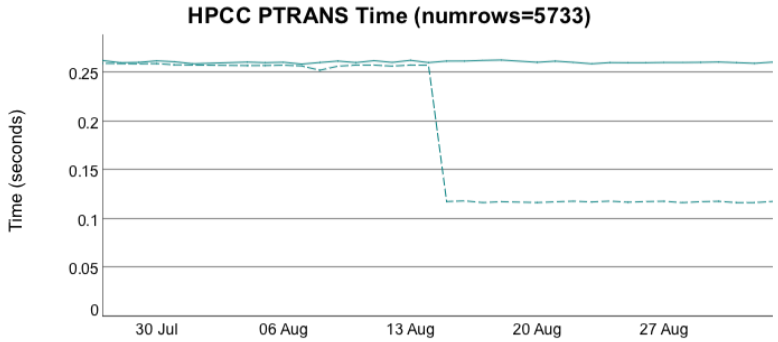


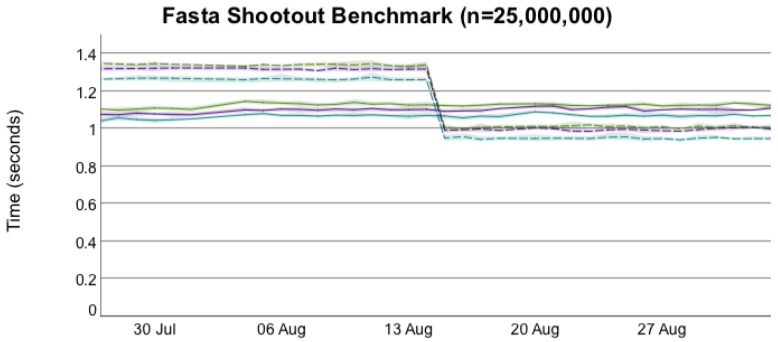
LLVM 4 Upgrade

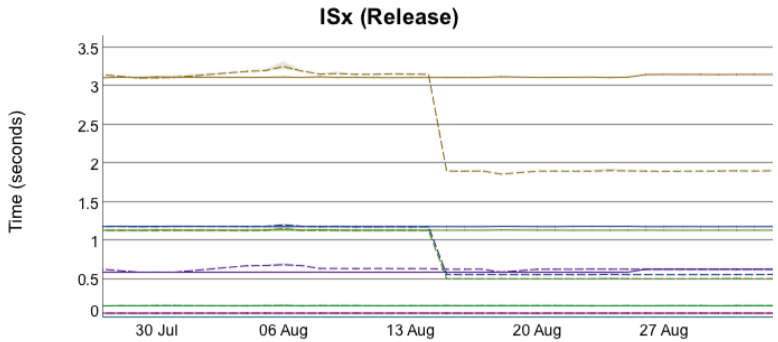
LLVM 4 Upgrade: This Effort and Impact

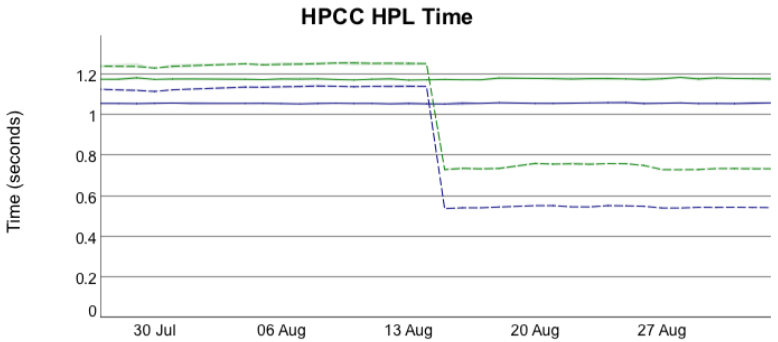
This Effort: Upgraded from llvm 3.7 to 4.0

Impact: Performance improvements for many benchmarks





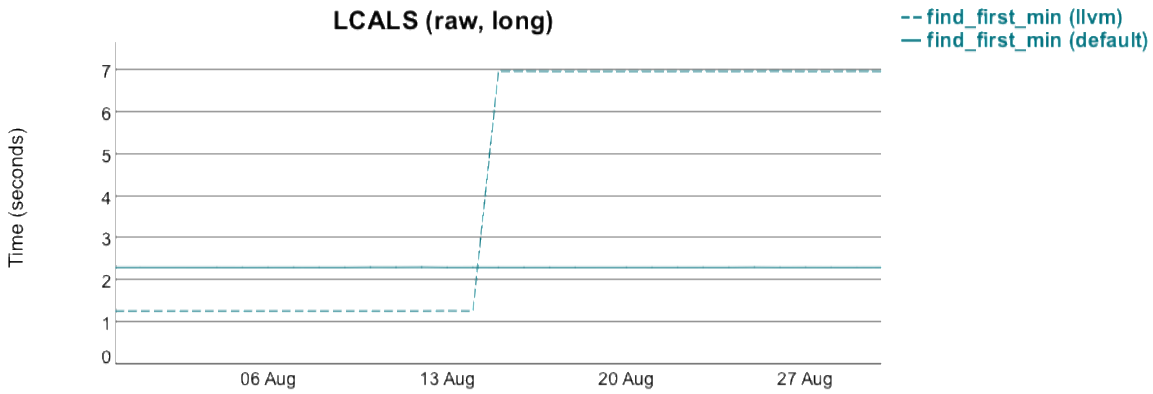




LLVM 4 Upgrade: Impact Cont.

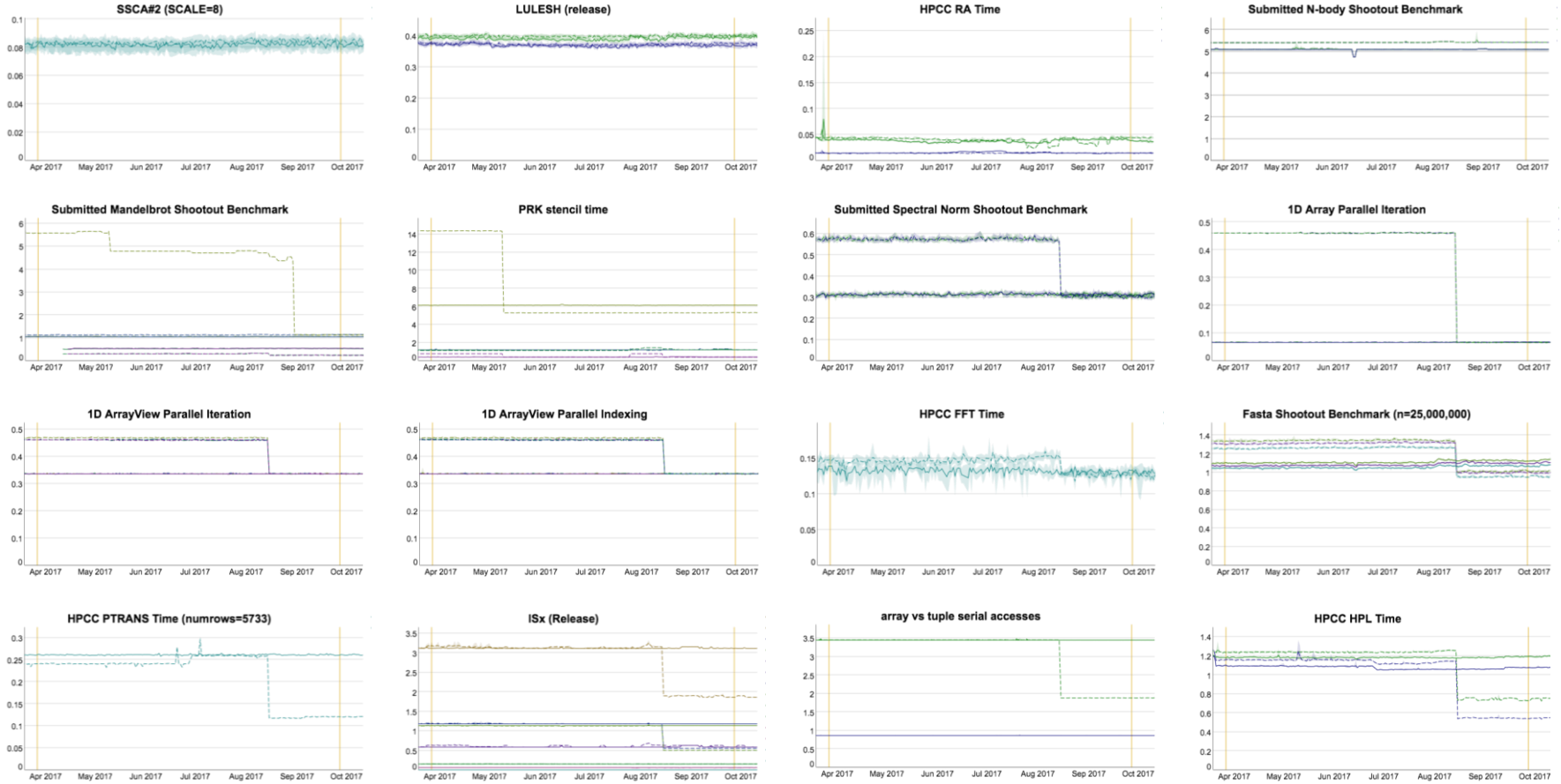
Impact: One surprising performance regression

- lcals find_first_min 6x slower (still need to investigate why)



LLVM: Summary

- Most benchmarks are now competitive with C back-end



LLVM: Status & Next Steps

Status: Ready to rely on LLVM more in Chapel project

- --llvm performance has generally improved
  - very competitive with the C back-end
  - significantly faster in some cases
- Chapel won't need internal clang headers with future versions of clang

Next Steps:

- Make --llvm the default back-end
  - Address any remaining performance differences first
- Remove uses of private clang headers
  - clang API has improved making these unnecessary in some cases
  - contributed a patch for clang 6 to enable us to remove the rest
- Complete ongoing efforts
  - Type-Based Alias Analysis Metadata improvements
  - Enabling --vectorize by default with --llvm

Partially Generic Resolution Changes

Partially Generic: Background

- Function resolution prefers 'where' clauses

```
proc f(x) where isIntegralType(x.type){
  writeln("f(x) where isIntegralType");
}
proc f(x) {
  writeln("f(x) generic)");
}
f(1);
// prints out “f(x) where isIntegralType”
```

Partially Generic: Challenge

- **What about this example?**

```
proc t1(A:[ ]) where true {
  writeln("t1(A:[ ]");
}
proc t1(A:[ ] int) {
  writeln("t1(A:[ ] int)");
}
var A:[1..100] int;
t1(A);
```

- **Before 1.16, produced an ambiguity error**
  - compiler added a 'where' clause to implement the ':[ ] int' argument
  - resulting in 2 fully generic overloads with where clauses
  - causing an ambiguity error in accordance with language specification

Partially Generic: This Effort

This Effort: Improved resolution rules

- Now prefer the ‘:[ ] int’ version
- More intuitive and in line with other resolution rules, namely:
  - existence of a 'where' clause is a last resort tie-breaker
  - arguments specifying a concrete type are preferred over generic arguments

Status: Implemented and documented in specification

Iterator Inlining Improvements

Iterator Inlining

Background: Could only inline iterators with a single yield

- Iterators that aren't inlined suffer significant performance penalty

This Effort: Permit iterators with multiple yields to be inlined

- For non-zippered iterators only
- Defaults to 10 yields, can be changed with --inline-iterators-yield-limit

Impact: More iterators can now be inlined

- Significantly improved performance of a user application
- No performance changes in our nightly suite
  - internal iterators have already been highly optimized

Next steps: Improve iterator inlining for zippered iterators

Dynamic Cast Optimization

Dynamic Casts

Background: Dynamic cast is a runtime check

- Check if a class instance has type that is a subtype of another type

```
class Parent { ... }
class Child : Parent { ... }
...
var p:Parent = ...;
var c = p:Child; // casts the object or returns nil if is not of that type
```

- Was implemented with a series of conditionals…

…that checked against every subtype

…so had O(# classes) code size, runtime complexity

This Effort: Improved dynamic cast to be constant time

Impact: Reduced generated code size in some cases

Other Compiler Improvements

Other Compiler Improvements

- Added support for #-based comments in '-f' configuration files
- Added --print-unused-functions to identify unused routines
- Improved CHPL_UNWIND output to include more functions
- Improved --print-callgraph output to include more functions
- Stopped heap-promoting local variables in on-clauses for 'qthreads'
- Removed support for the deprecated array alias '=>' operator
- Removed the --conditional-dynamic-dispatch-limit flag and feature
  - rely on existing dynamic-dispatch table instead

Error Message Improvements

Error Message Improvements

- improved 'const' checking
- extended --div-by-zero-checks to also check for modulus (%) 0 operations
- added an error message for exported functions with generic arguments
- improved error messages for illegal 'delete' statements
- removed checks that iterators must contain 'yield' statements
- added an error for records that try to subtype another type
- added a number of error messages for poorly formed (or unsupported) init()s
- improved the error message generated when closing a file before its channels
- added an error for returning a tuple of the wrong size
- improved an error message for bad forwarding calls to parallel iterators
- improved an error message about type mismatches between fields

Bug Fixes

Bug Fixes

- fixed a number of bugs related to initializers
- fixed a number of bugs related to error-handling
- fixed several bugs in the 'forwarding' feature for object fields
- fixed bugs in counting tasks and creating the right number of new tasks
- fixed bugs for several forall intent cases
- fixed a bug in which a qualified module reference was incorrectly shadowed
- fixed a bug in isAlpha() for characters between upper- and lowercase letters
- fixed a bug in bulk assignment for rank-change slices
- fixed a bug in variable deinitialization order
- fixed a bug in which 'use' statements were not considered in program order
- fixed a bug in which 'rmTree' would not remove directories with hidden files

More Bug Fixes

- fixed some bugs in loop invariant code motion (LICM)
- fixed a portability bug in padding years in the DateTime module
- fixed a bug in dead code elimination relating to local record types
- fixed a bug comparing floating point expressions on linux32
- fixed a bug in complicated type aliases
- fixed a bug in denormalization for '~' for small integers
- fixed a bug in which remote-value forwarding didn't handle dereferences well
- fixed a bug relating to scoped accesses to internal modules
- fixed bugs with parallel iteration over domains with non-natural alignment
- fixed a bug in the implementation of the &= operator for associative domains
- fixed a bug in applying 'reindex()' to an empty domain/array

Even More Bug Fixes

- fixed a bug in modules with just one non-initialization function declaration
- fixed a bug in dead code elimination for do-while loops
- fixed a bug in which isRecord*() returned 'true' for sync/single types
- fixed a bug related to task counters not being stored in task-local storage
- fixed a bug for ambiguous 'param' methods
- fixed a bug in 'fifo' tasking in which not enough threads were created

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