Generated Code Improvements

Chapel Team, Cray Inc.

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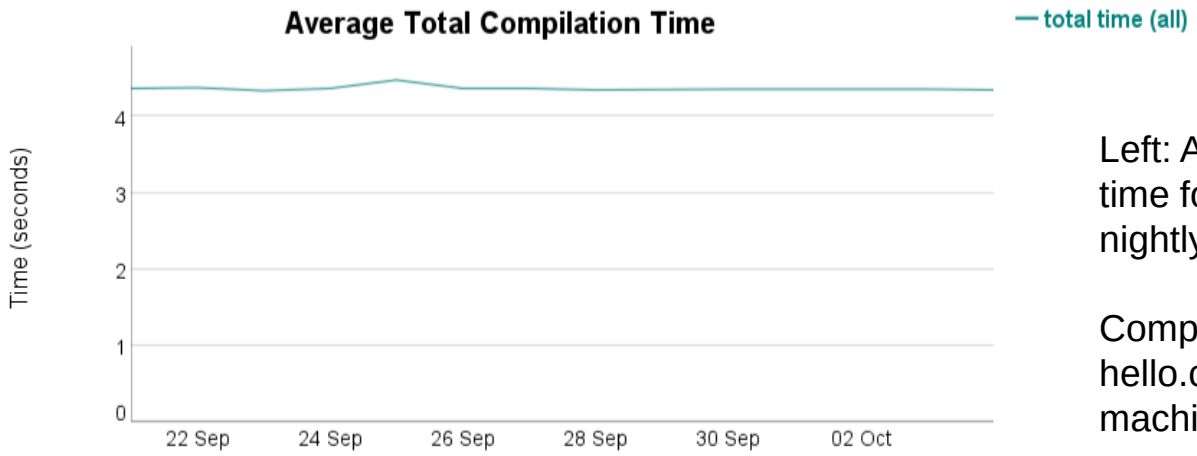
Outline

- Incremental Compilation
- Denormalize Pass
- Vectorization Changes
- LLVM Debug Information
- Other Generated Code Improvements

Incremental Compilation

Incremental Compilation: Background

- **Compiler analyzes whole program at one time**
  - This includes recompilation of standard library code
- **[Re]compilation is relatively slow**
  - Even for minor changes to a small application
- **Goal: provide a quick recompilation mode for users**

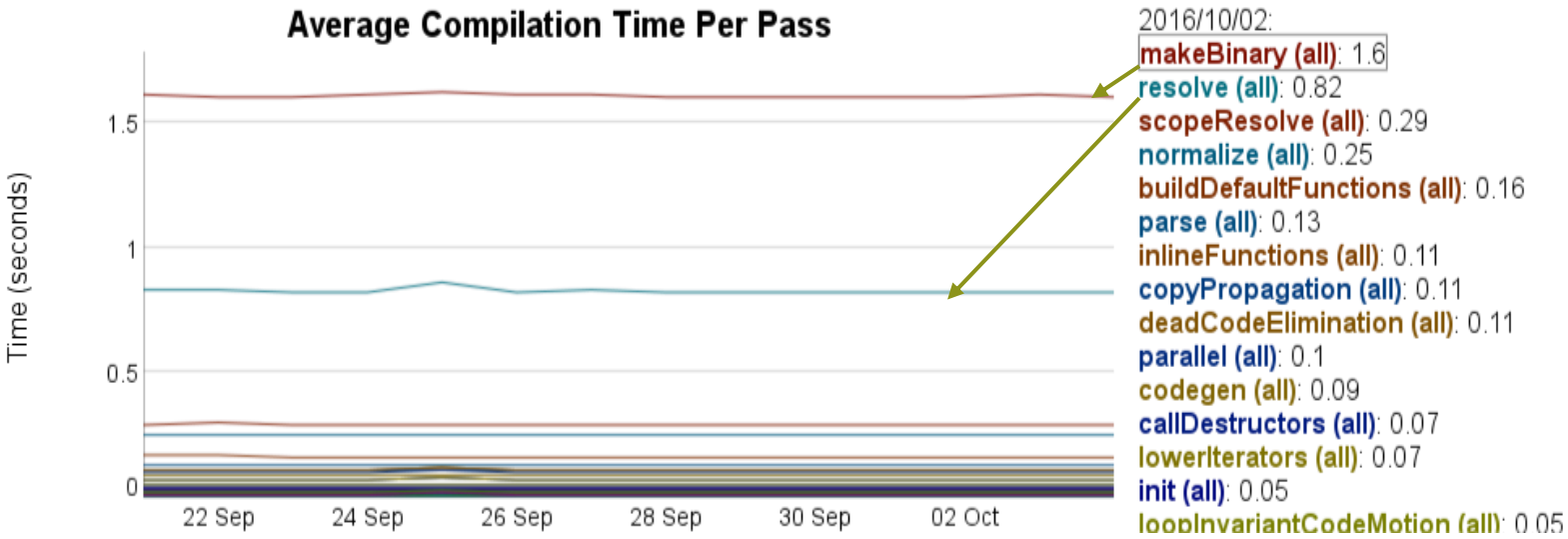


Left: Average compilation time for all tests in our nightly testing suite.

Compilation time for hello.chpl on the same machine is ~3.4 seconds

Incremental Compilation: Background

- **Majority of time spent in 2 passes:**
  - makeBinary – compilation of generated C code
  - functionResolution – type resolution and resolving function calls
- **Improvements here would benefit compilation significantly**
  - makeBinary accounts for ~40% of the compilation time



Incremental Compilation: This Effort

- **Google Summer of Code project**
  - Work from Kushal Singh at IIIT Hyderabad
  - Description of current work and future plans available in CHIP 15
- **Preliminary design for functionResolution pass**
- **Implementation work on codegen/makeBinary passes**

Incremental Compilation: This Effort

- **Preliminary design for functionResolution pass**
  - Including list of cases where a function would need recompilation:
    - Changes to its body
    - Changes to declaration of functions it depends on
    - New potential matches when resolving calls within its body
  - Lower implementation priority than makeBinary

Incremental Compilation: This Effort

- **Implementation work on codegen/makeBinary**
  - makeBinary compiles every generated .c file into one monolithic .o file
    - Any change to one file would trigger a complete rebuild of this .o
  - Moved to generating two .o files and linking them together
    - One for user code, one for library code
    - User changes hopefully would not modify library .o file, saving recomp time
  - Required “purifying” generated header file
    - Moved definitions into another file but left declarations in place
    - In incremental mode, removed “static” keyword from exported symbols
    - Allowed header to be #included by both .o files w/o link time errors

Incremental Compilation: This Effort

- **How to reuse the unmodified parts of the generated code?**
  - Codegen always generated completely new copies of the .c files
    - Even if some of the files would be identical to previous versions
  - Need to maintain persistent state between compiles
    - Compare new generated code against persistent copy…
    - … and move the changed code into the persistent storage location, …
    - … then rebuild only the touched parts of the persistent state
  - Remove the persistent state if changes detected in:
    - Compilation flags
    - Environment variables
    - Changes in library code effectively yield the same result
    - Can be more selective later, but not a high priority

Incremental Compilation: This Effort

- **Add flag to enter this compilation mode, --incremental**
  - Generates two .o's instead of one
  - During first run, saves persistent state and current compilation options
    - Subsequent runs perform check, then overwrite persistent state as needed
- **Challenge: generated .c must be stable, but currently isn't**
  - i.e. An unmodified application should always yield the same .c files
    - Today we see differences in the ordering of functions from run to run
    - This means we must overwrite the persistent state too frequently

Incremental Compilation: Status

- **Known Issues**
  - Generated .c code not completely stable
  - No support for the LLVM back-end
  - Will differ in execution performance from a normal compile
    - Certain gcc optimizations thwarted by multiple .o's, removing static keyword

Incremental Compilation: Next Steps

- **Finish stabilizing generated C code**
- **Discuss next steps before function resolution changes**
- **Make our library .o file reusable across different programs**
  - This would speed up compile time for all programs, not just recompiles
  - Challenge: library code is highly generic and varies with user code
- **Add framework for recompilation to function resolution**
  - Including persistent storage of AST dependencies for functions
- **Other compilation time improvements**

Denormalize

Denormalize: Background

- Generated C code includes a lot of temporary variables
- Consider this Chapel code:

```
var x = 123;
writeln(x*x + x);
```

- It generates the C code:

```
int64_t call_tmp_chpl;
int64_t call_tmp_chpl2;
call_tmp_chpl = (INT64(123) * INT64(123));
call_tmp_chpl2 = (call_tmp_chpl + INT64(123));
writeln_chpl2(call_tmp_chpl2);
```

- The C compiler often optimizes these temps away, but
  - it has to work to do so
  - they increase the complexity for developers looking at the generated C

Denormalize: Background

- Most of the Chapel compiler works with *normalized* AST
- AST is *normalized* so there are no nested call expressions

```
x*x + x
```

becomes

```
call_tmp = x*x
call_tmp + x
```

- The *normalize* pass adds these call_tmp temporaries
- Later passes rely on call expressions not being nested

Denormalize: This Effort

- **Add a pass to remove these call temporaries**
- **Pass runs just before generating C code**
  - only codegen needs to be able to work with a denormalized AST

Denormalize: Impact

- **Remember this Chapel code:**

```
var x = 123;
writeln(x*x + x);
```

- **With --denormalize, it generates C code like**

```
writeln_chpl2( (INT64(123) * INT64(123)) + INT64(123));
```

- **Results in a 25%-50% reduction in lines of C code**

Multi-slide topic: Status and Next Steps

Status:

- --denormalize available in 1.14 release
  - off by default due to insufficient testing prior to release

Next Steps:

- turn --denormalize on by default
- consider further improvements to code generation to clean up
  - useless casts
  - unnecessary parentheses
- improve --denormalize to cover more cases
  - e.g. function calls with a single argument

Changes to --vectorize

Chapel Vectorization: Background

- **Chapel is well-suited for vectorization**
  - limited aliasing
  - support for array programing

```
A = B + C;
```

  - parallelism is a first class citizen

```
forall i in 1..10 do …
```

- **Need to convey Chapel semantics to back-end**
  - do not want to generate explicit vectorization
    - rather, convey when vectorization is legal
    - leverage back-end compilers' sophisticated and refined cost models

Changes to --vectorize

Background:

- Added --vectorize in 1.11.0
- It finds and marks order-independent (data parallel) loops
- And attaches “#pragma ivdep” to the generated code
  - ivdep == ignore vector dependencies
- In 1.14.0, we saw data parallel loops that had vector dependencies
  - in particular with reductions, likely also any loop with “task-private” vars
  - realized order-independence is not sufficient for asserting ivdep

This Effort:

- Stopped enabling --vectorize with --fast
  - is now an opt-in (use at your own risk) flag

Next Steps:

- Determine what additional analysis is needed to safely use ivdep
- Continue exploring other vectorization strategies

LLVM Debug Information

LLVM Debug Information

Background: Chapel includes --llvm code generation option

- generates LLVM IR instead of C code
- initially added in 1.6.0
- supports several research projects
- but, did not generate debug information with -g

This Effort: Include debug information in generated LLVM IR

- contributed to by Matt Baker, Hui Zhang
- finished as part of Google Summer of Code

Impact: --llvm -g works to debug Chapel programs

- debugger can show Chapel source code lines
- debugger can show Chapel global variables

Next Steps: Further improve the debug experience

- make debug variable names match Chapel source code
- generate debug information for local variables

Other Generated Code Improvements

Other Generated Code Improvements

- **Improved accuracy of #line directives for vars, procs**
  - Improves debugging of Chapel code through the generated C
- **Improved quality of 'local' blocks in generated C code**
  - merged adjacent blocks to reduce curly braces
  - added a "/* local block */" comment for developers

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