Faster Haskell

Neil Mitchell

www.cs.york.ac.uk/~ndm

The Goal

- Make Haskell *"faster"*
  - Reduce the runtime
  - But keep high-level declarative style

- Full automatic - no "special functions"
  - Different from foldr/build, steam/unstream
- Whole program optimisation
  - But fast (developed in Hugs!)

Word Counting

- In Haskell

```
main =
   print . length . words =<< getContents
```

- Very high level
- A nice “specification” of the problem

Note: getContents reimplemented in terms of getchar

And in C

```
int main() {
    int i = 0, c, last_space = 1;
    while ((c = getchar()) != EOF) {
        int this_space = isspace(c);
        if (last_space && !this_space) i++;
        last_space = this_space;
    }
    printf("%i\n", i);
    return 0;
}
```

About 3 times faster than Haskell

Why is Haskell slower?

- Intermediate lists! (and other things)
  - GHC goes through 4Gb of memory – O(n)
  - C requires ~13Kb – O(1)

- length . words =<< getContents
  - getContents produces a list
  - words consumes a list, produces a list of lists
  - length consumes the outer list

Removing the lists

- GHC already has foldr/build fusion
  - map f (map g x) == map (f . g) x
- But getContents is trapped under IO
  - Much harder to fuse automatically
  - Don’t want to rewrite everything as foldr
  - Easy to go wrong (take function in GHC 6.6)

Supero: My Optimiser

- Fully automatic
  - No annotations, special functions
- Evaluate the program at *compile* time
  - Start at main, and execute
- Stop when you reach a primitive
  - The primitive is in the optimised program

With wordcount

```
main r
(print . length . words =<< getContents) r
(getContents >>= print . length . Words) r
case getContents r of (# s, r #) -> …
getChar >>= if c == 0 then return [] else …
case getChar r of …
```

- Have reached a case on a primitive

The new program

```
main r = case getChar r of
                    (# c, r #) -> main2 c r
```

- Create main2, for the alternative
- Continue optimisation on the branches of the case, main2
- The evaluation mainly does inlining
  - Also case/case, case/ctor, let movement

Tying in the knot

- Each name in the new program corresponds to an expression in the old
  - main = print . length . words =<< getContents
  - main2 = the case alternative

- If you reach the same expression, use the same name – makes recursive call

Summing a list

```
sum x = case x of
                  [] -> 0
                  (x:xs) -> x + sum xs

range i n = case i > n of
                   True -> []
                   False -> i : range (i+1) n

main n = sum (range 0 n)
```

Evaluate

```
main n
sum (range 0 n)
main n = main2 0 n
    where main2 i n = sum (range i n)
case range i n of {[] -> 0; x:xs -> x + sum xs}
case (case i > n of {True -> []; False -> …}) of …
case i > n of {True -> 0
                    ;False -> i + sum (range (i+1) n)}
```

tie back: main2 (i+1) n

The Result

```
main n = main2 i n

main2 i n = if i > n then 0 else i + main2 (i+1) n
```

- Lists have gone entirely
- Everything is now strict
- Using sum as foldl or foldl' would have given accumulator version

Ensuring Termination

- To make the optimisation terminate
  - Need to “hide” some information
  - Anything which is an *accumulator*
  - i.e. foldl’s 2nd argument
- Lots of possible termination criteria
  - Want to give good optimisation
  - But not blow up the size of the code

Termination Problems

- One theme – bound recursion depth
- Problem 1:
  - Some optimisations require ~5 recursive inlinings
  - 5 recursive inlinings blows up code a lot
- Problem 2:
  - Repeated application can *square* any bound
  - Bound of 5 can become a bound of 25!

Back to word counting

- What if we use Supero on the Haskell?
  - Compile using yhc, to Yhc.Core
  - Optimise, using Supero
  - Write out Haskell, compile with GHC
- GHC provides:
  - Strictness/unboxing
  - Native code generator

Problem 1: isSpace

- On GHC, isSpace is too slow (bug 1473)
  - C's isspace: 0.375
  - C's iswspace: 0.400
  - Char.isSpace: 0.672

- For this test, I use the FFI

SOLVED!

Problem 2: words

```
words :: String -> [String]
words s =  case dropWhile isSpace s of
       "" -> []
       s' -> w : words s''
             where (w, s'') = break isSpace s'
```

- Does two extra isSpace tests per word
- Better version in Yhc

SOLVED!

Other Problems

- Wrong strictness information (bug 1592)
  - IO functions do not always play nice
- Badly positioned heap checks (bug 1498)
  - Tight recursive loop, where all time is spent
  - Allocates only on base case (once)
  - Checks for heap space every time
- Unnecessary stack checks
- Probably ~15% slowdown

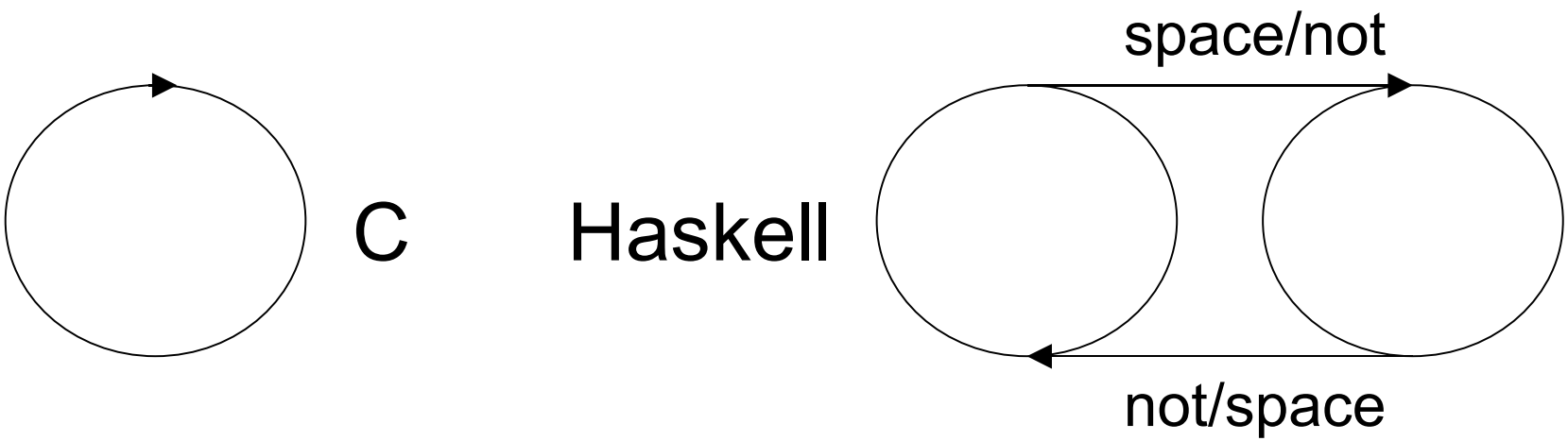
Pending

Performance

- Now Supero+GHC is 10% faster than C!
  - Somewhat unexpected…
  - Can anyone guess why?

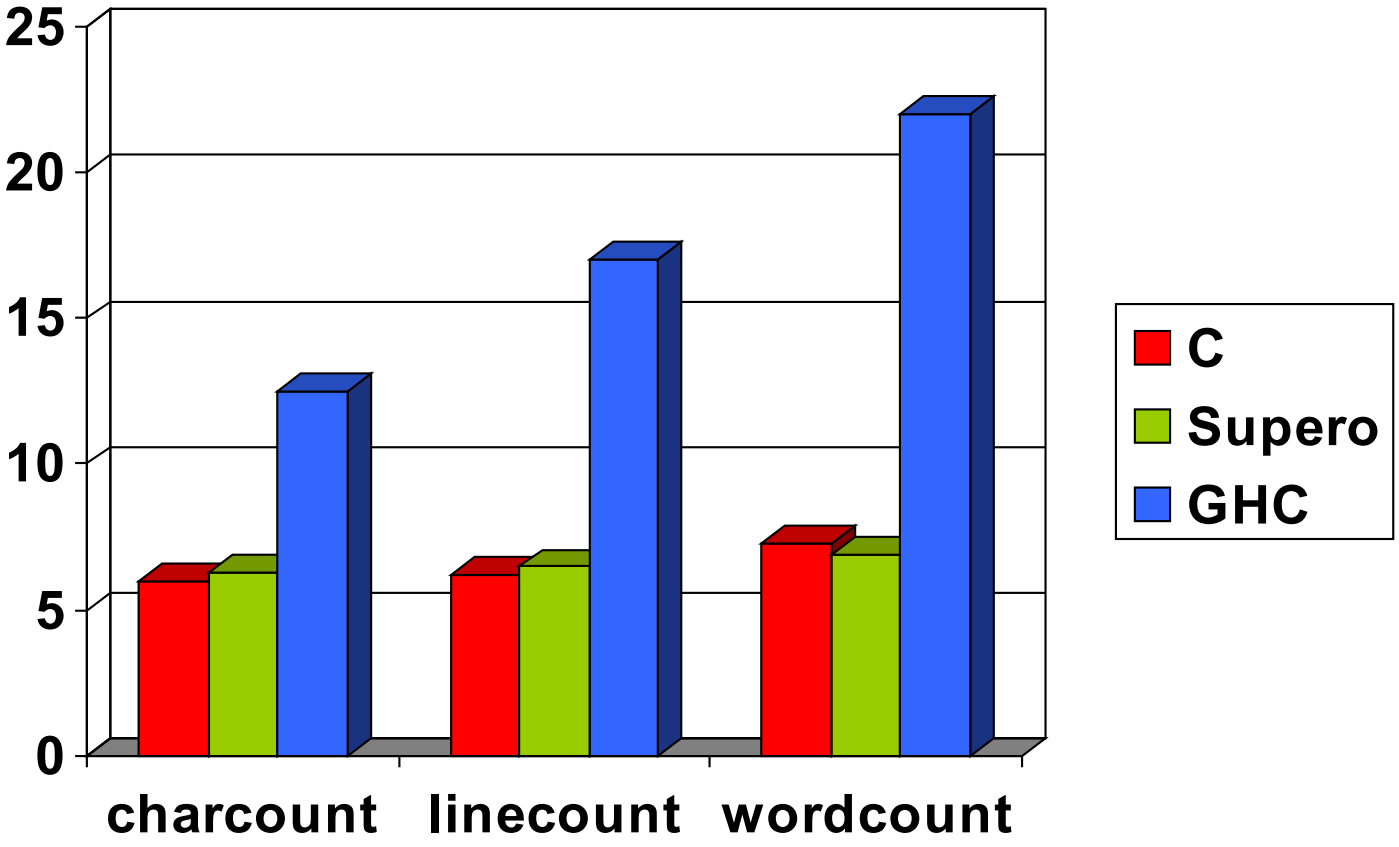
```
while ((c = getchar()) != EOF)
    int this_space = isspace(c);
    if (last_space && !this_space) i++;
    last_space = this_space;
```

The Inner Loop



- Haskell encodes space/not in the program counter!
- Hard to express in C

The “wc” benchmark



Haskell Benchmarks

- Working towards the nofib/nobench suite
  - Termination vs optimisation problem
  - Massively more complex
  - Much larger volumes of code
- Particular issues
  - The read function
  - Invoking a Haskell lexer to read an Int!
  - List comprehensions (as desugared by Yhc)

Conclusions

- Still lots of work to do before concluding!
  - Nobench is a priority

- Haskell can be both beautiful *and* fast

Thanks to: Simon Peyton Jones, Simon Marlow, Tim Chevalier for low-level GHC help