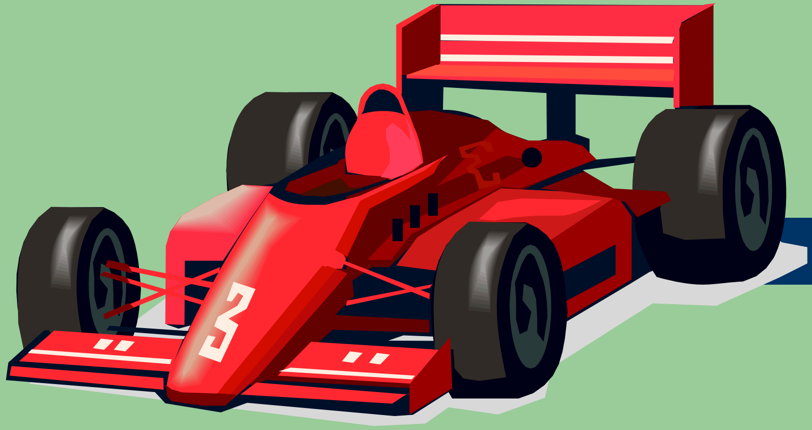
Supercompilation for Haskell



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The Goal

- Make Haskell *‘faster’*
  - Reduce the runtime
  - But keep high-level declarative style
- Without user annotations
  - Different from foldr/build, steam/unstream

Word Counting

- In Haskell

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

- Very high level
- A nice ‘specification’ of the problem

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 (gcc vs ghc)

Why is Haskell slower?

- Intermediate lists! (and other things)
  - GHC allocates and garbage collects memory
  - C requires a fixed ~13Kb

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

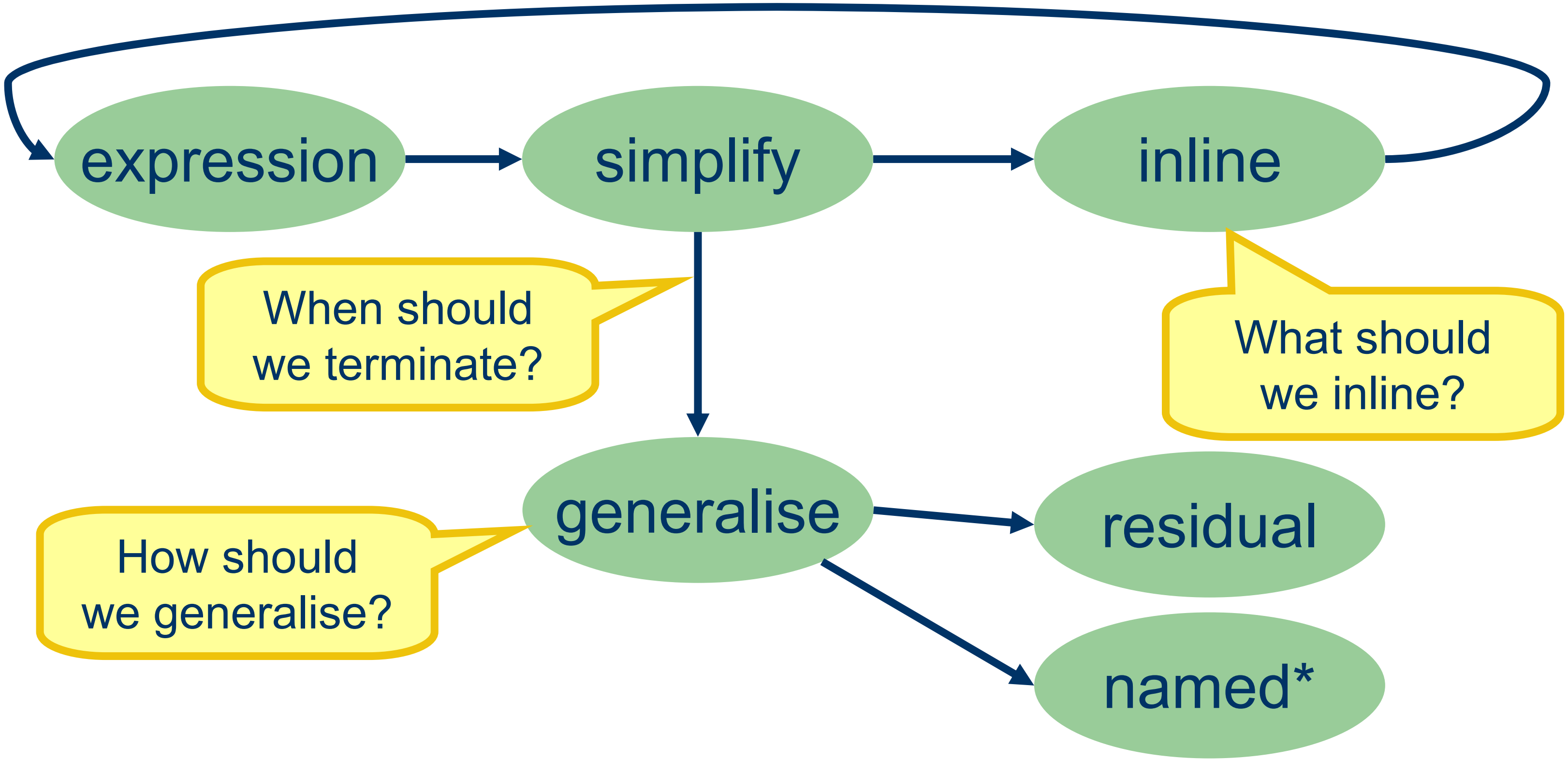
Removing the lists

- GHC already has foldr/build fusion
  - e.g. 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)

Supercompilation

- An old idea (Turchin 1982)
- Whole program
- Evaluate the program at *compile* time
  - Start at main, and execute
- If you can't evaluate (primitives) leave a residual expression
  - The primitive is in the optimised program

Optimising an expression



An example (specialisation)

map (\b → b+1) as -- named as map’

- inline map

case as of {[] → []; x:xs -> (\b → b+1) x : map (\b → b+1) xs}

- simplify

case as of {[] -> []; x:xs → x+1 : map (\b → b+1) xs}

- no generalisation and residuate

case as of {[] -> []; x:xs → x+1 : ? xs}

? xs = map (\b → b+1) xs

- use existing name

? xs = map’ xs

map’ xs = case as of {[] → []; x:xs → x+1 : map’ xs}

An example (deforestation)

map f (map g as) -- named as map'

- inline outer map

case map g as of {[] $\rightarrow$ []; x:xs $\rightarrow$ f x : map f xs}

- inline remaining map

case (case … of …) of {[] $\rightarrow$ []; x:xs $\rightarrow$ f x : map f xs}

- simplify

case as of {[] $\rightarrow$ []; x:xs $\rightarrow$ f (g x) : map f (map g xs)}

- generalise, residuate and use existing name

map' f g as = case as of {[] $\rightarrow$ []; x:xs $\rightarrow$ f (g x) : map' f g xs}

An example (with generalisation)

```
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)
```

Evaluation proceeds

sum (range 0 n)

case range 0 n of {[] → 0; x:xs → x + sum xs}

case (case 0 > n of {True → []; False → …}) of …

case 0 > n of {True → 0;False → i + sum (range (0+1) n)}

sum (range (0+1) n)

- Now we terminate and generalise!

sum (range i n)

case range i n of {[] → 0; x:xs → x + sum xs}

…

The Residual Program

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

When do we terminate?

- When the expression we are currently at is an extension of a previous one

sum (range (0+1) n) > sum (range 0 n)

a > b iff a $\rightarrow_{emb}^{*}$ b, where emb = $\{f(x_1,\ldots,x_n) \rightarrow x_i\}$

- This relation is a homeomorphic embedding
  - Guarantees termination as a whole

How do we generalise?

- When we terminated which bit had emb applied?

sum (range <u>(0+1)</u> n)

- Generalise those bits

let i = 0+1

in sum (range i n)

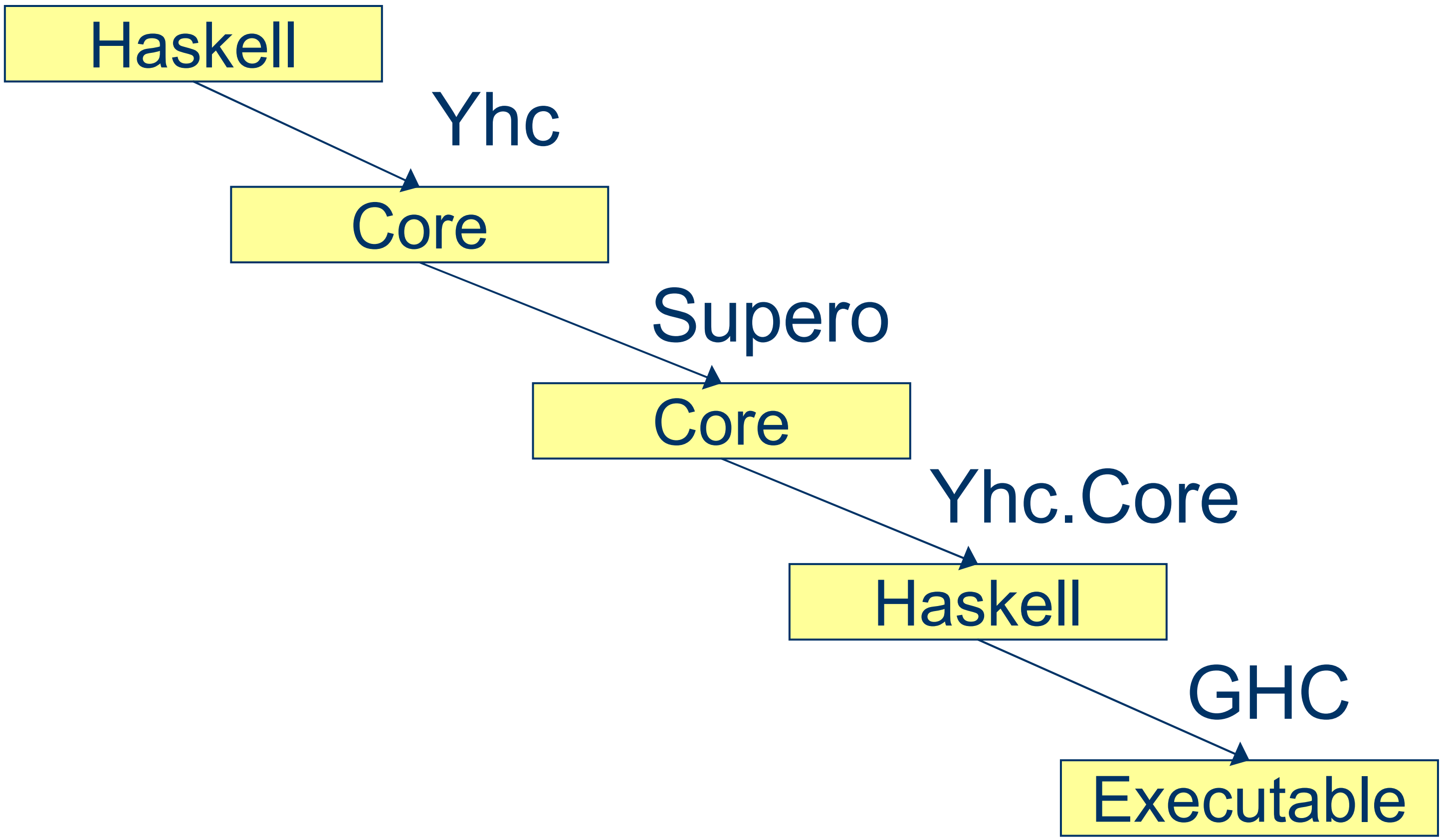
What should we inline?

- Obvious answer: whatever would be evaluated next. But…

```
let x = (==) $ 1
in x 1 : map x ys
```

- We want to evaluate $, as map will terminate
- Inline by evaluation order, unless will terminate, in which case try others

‘Supero’ Compilation



GHC's Contributions

- GHC is great ☺
  - Primitives (Integer etc)
  - Strictness analysis and unboxing
  - STG code generation
  - Machine code generation

- How do we do on word counting now?

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 (spot 2 bugs!)

```
words :: String → [String]
words s =  case dropWhile isSpace s of
        [] → []
        s2 → w : words s3
              where (w, s3) = break isSpace s2
```

- 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

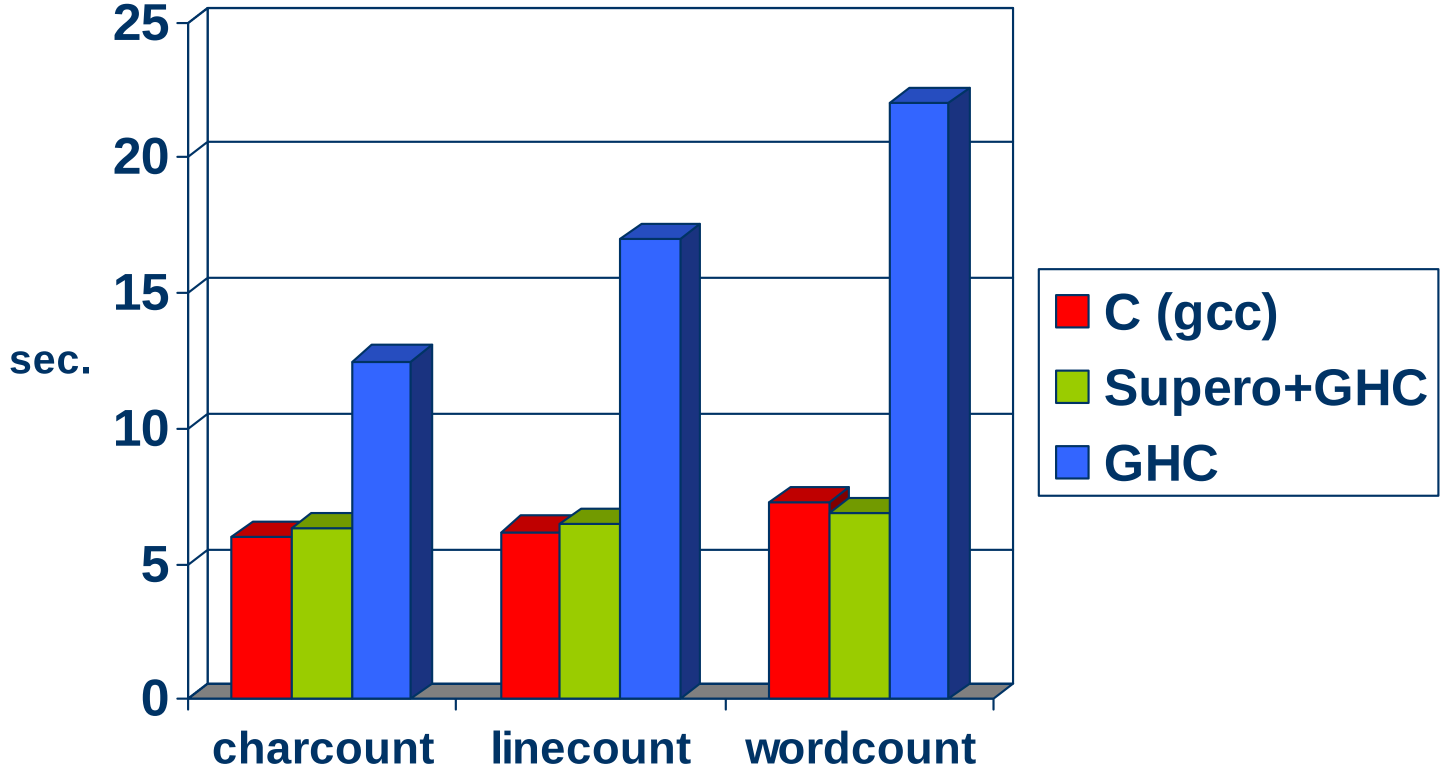
- Now Supero+GHC is 10% faster than C!
  - Somewhat unexpected…
  - Can anyone guess why?

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

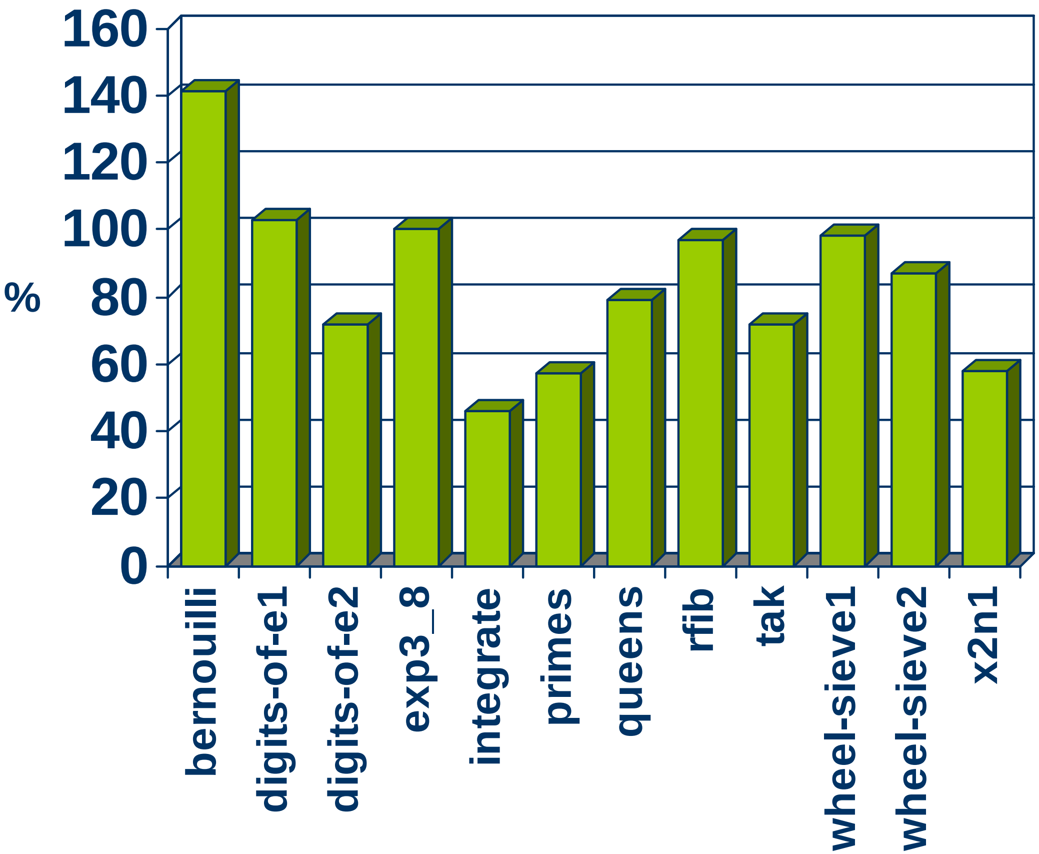
The Inner Loop

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

Comparative Runtime (40Mb file)



Runtime as % of GHC time



Conclusions

- Still more work to be done
  - More benchmarks, whole nofib suite
  - Compilation time is currently too long

- Haskell can perform as fast as C
- Haskell programs can go faster