

Rebooting Supercompilation for Haskell

Ömer S. Ağacan
oagacan@indiana.edu

Ryan R. Newton
rrnewton@indiana.edu

August 27, 2015

Rebooting Supercompilation for Haskell - Talk outline

- An overview of supercompilation.

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- What's interesting about it in the context of Haskell? Current state-of-the-art.

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- Overview of how it works.
- "But where's my supercompiler for Haskell?" My preliminary work and research goals.

Supercompilation: An overview

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 - When evaluating sub-expressions of a case expression, propagate information about current branch(shape of the scrutinee).

```
case v of  
  P v1 .. vN → expr
```

Evaluate $expr[P\ v_1 .. v_N/v]$.

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case v of
 $P \ v_1 \ .. \ v_N \rightarrow \text{expr}$

Evaluate $\text{expr}[P \ v_1 \ .. \ v_N / v]$.

- Most of the time the goal is to generate more efficient programs. (but see Klyuchnikov and Romanenko [2010] for a different use of supercompilation)

Supercompilation in the context of Haskell

- Why is it interesting?
- In a sense, it's the "ultimate" optimization. ("-O99")
- This optimizes in the sense that:
If we have a programs \mathcal{P}_1 and \mathcal{P}_2 , and
 $\mathcal{P}_1 \Downarrow v$ in N steps and
 $\mathcal{P}_2 \Downarrow v$ in M steps,
we consider \mathcal{P}_2 optimized if $M < N$.
- An approximation, but works well in practice.
(i.e. if $M < N$ then usually M is a faster program)

Supercompilation in the context of Haskell

It generalizes:

- Deforestation(Wadler [1988])
- Partial evaluation
- Call-pattern specialization(Peyton Jones [2007])
- Ad-hoc optimizations via rewrite rules, e.g. shortcut fusion (Gill et al. [1993]) or library-specific rewrite rules
- "Optimizing SYB is Easy!" (Adams et al. [2014]) and "Optimizing Generics is Easy!" (Magalhães et al. [2010]) style "domain-specific" partial evaluators
- Function specialization(SPECIALIZE pragmas)
- ... and many more

Current state-of-the-art

- Bolingbroke [2013] shows some great potential:
 - Up to 20x faster runtime.
 - Up to 100% reduction in allocation.
- But it also suffers from problems that are inherent to supercompilation:
 - "We do not attempt to supercompile the full Nofib suite because the other Nofib benchmarks are considerably more complicated and generally suffer from extremely long supercompilation times."
(Jonsson [201?] focuses on compilation performance, and reports *<3 seconds* for all the small programs from Nofib)
 - Up to 132x compile time.
 - Up to 2.8x generated code size.

How it works? An overview

Bolingbroke [2013] laid out a great framework for supercompiling Haskell:

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- **Matching:** Evaluating open terms lead to loops. Matcher tries to detect loops, returns information about how to refer to this new loop.
- **Termination checking:** Because perfect matcher is not possible, and some programs just loop.

mapOfMap f g = map f . map g

h1 f g a = map f (map g a)

...

h4 f g a =

case (case a of

 [] -> []

 h1 : t1 -> g h1 : map g t1) of

 [] -> []

 h0 : t0 -> f h0 : map f t0

...

h6 f g a =

case a of

 [] -> []

 h : t -> f (g h) : map f (map g t)

h7 f g a =

case a of

 [] -> []

 h : t -> f (g h) : h7 f g t

Problems with supercompilation operations

Each operation has hard problems to solve.

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Propagating too much information may lead to work duplication.

```
let n = fib 100
    b = n + 1
    c = n + 2
in (b, c)
```

```
let b =
    let f = <fib, unrolled a few times>
    in f + 1
    c =
    let f = <fib, unrolled a few times>
    in f + 2
in (b, c)
```

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Splitter: (from Bolingbroke [2013])

Propagating too little information may lead to missing optimization opportunities.

```
let map = ...  
    ys = map f zs  
    xs = map g ys  
in Just xs
```

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```
xor x y = case x of True -> not y; False -> y
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goal = (xor a b, xor c c)
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h1 = (h0 a b, h0 c c)
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```
h1 x = case x of True -> False; False -> False
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```
h2 = (h0 a b, h1 c)
```

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Termination checker:

Some programs just loop.

```
loop n = loop (n + 1)
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```
countFrom n = n : countFrom (n + 1)
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Termination checker:

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countFrom n = n : countFrom (n + 1)
```

Sometimes detecting loops is not so easy: (growing arguments)

```
reverse_acc [] acc = acc
reverse_acc (h : t) acc = reverse_acc t (h : acc)
goal lst = reverse_acc (reverse_acc lst []) []
...
h_ lst = ... reverse_acc t1 (h1 : []) ...
...
h_ lst = ... reverse_acc t2 (h2 : h1 : []) ...
...
```

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 - Working at Core level is hard. (partial functions, invariants etc.)

Conclusions

Have a working implementation of supercompiler described in Bolingbroke [2013].

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Collecting benchmark programs - send yours! (with expected optimizations)

We can create a benchmark suite like Nofib, but for supercompilation-specific problems. (pathological cases, programs with lots of intermediate data structures)

Once we have a working implementation:

- Focus on specific parts(matcher, splitter etc.). Try other ideas from the literature(e.g. homeomorphic embedding).
- Work on some of the obvious improvements, like parallelizing the matcher.
- More experimental ideas:
 - Can we formulate it as a search problem and apply ideas from the literature?
 - Is profile-driven decision making possible?
 - Can we make use of existing rewrite rules mechanism?

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- More experimental ideas:
 - Can we formulate it as a search problem and apply ideas from the literature?
 - Are profile-driven decision making possible?
 - Are machine learning algorithms applicable?

Thanks!

Github: [osa1/sc-plugin](#) IRC: [osa1](#) Mail: oagacan@indiana.edu

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