

# Rebooting Supercompilation for Haskell

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# 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.

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- High-level idea:
  - Evaluate programs in compile-time, while making the most out of known inputs and definitions.
    - Definitions of used functions.
    - Statically known arguments of functions.
    - When branching, propagate learned information through branches and make use of that information while compiling branches. (case expressions)

# Supercompilation: An overview

- The paper that describes the idea in English: "The Concept of a Supercompiler" Turchin [1986].
- High-level idea: (contd)
  - Evaluate programs in compile-time, while making the most out of known inputs and definitions.
    - 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.

# 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 95.1% reduction in runtime.
  - Up to 100.0% 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 +132002.0% in compile time.
  - Up to +188.9% in 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.

## How it works? An overview

```
mapOfMap f g = (.) (map f) (map g)
```

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

```
h2 f g a =  
  (\f lst -> case lst of  
    []      -> []  
    h : t   -> f h : map f t) f (map g a)
```

```
h3 f g a =  
  case (map g a) of  
    []      -> []  
    h : t   -> f h : map f t
```

## How it works? An overview

```
h3 f g a =  
  case (map g a) of  
    []      -> []  
    h : t -> f h : map f t
```

```
h4 f g a =  
  case (case a of  
    []      -> []  
    h1 : t1 -> g h1 : map g t1) of  
    []      -> []  
    h0 : t0 -> f h0 : map f t0
```

## How it works? An overview

```
h4 f g a =  
  case (case a of  
        []      -> []  
        h1 : t1 -> g h1 : map g t1) of  
    []      -> []  
    h0 : t0 -> f h0 : map f t0
```

Case-of-case transformation: (Jones and Santos [1998])

```
h5 f g a =  
  case a of  
    [] -> case [] of  
        []      -> []  
        h0 : t0 -> f h0 : map f t0  
    h1 : t1 ->  
      case (g h1 : map g t1) of  
        []      -> []  
        h0 : t0 -> f h0 : map f t0
```

## How it works? An overview

```
h5 f g a =  
  case a of  
    [] -> case [] of  
      [] -> []  
      h0 : t0 -> f h0 : map f t0  
    h1 : t1 ->  
      case (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)
```

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h6 f g a =  
  case a of  
    []      -> []  
    h : t   -> f (g h) : map f (map g t)
```

---

map f (map g t)

Looks similar to:

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

## How it works? An overview

At this point splitter tell us there's a loop.

```
h7 f g a =  
  case a of  
    []      -> []  
    h : t -> f (g h) : h7 f g t
```

Supercompiled version doesn't generate intermediate list.

# 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)
```

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**Splitter:** (from Bolingbroke [2013])

Propagating too much information may lead to work duplication.

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

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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Matcher:

May lead to work sharing, which may increase memory residency. (Chitil [1997])

```
S0 =  
  let a = fib y  
      b = fib y  
  in (a, b)
```

```
S1 =  
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```

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Or:

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```
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  in (a, b)
```

```
S1 =  
  let a = fib y  
  in (a, a)
```

Or:

```
S0 = sum [1 .. 1000] + prod [1 .. 1000]  
S1 = let l = [1 .. 1000] in sum l + prod l
```

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Termination checker:

Some programs just loop.

```
loop n = loop (n + 1)
```

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

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Termination checker:

Some programs just loop.

```
loop n = loop (n + 1)
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 : []) ...
...
```

# "Where's my supercompiler for Haskell?"

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- The goal here is to distribute it as a package, downloadable from Hackage.

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- I'm rebooting the supercompiler!
- The goal here is to distribute it as a package, downloadable from Hackage.
- Then the research will follow.

# Current status and problems

There has been some changes in GHC:

- Some changes in the Core theory: Roles.
- Lots of refactoring.

GHC API related problems:

- Some needed internals are not exposed by GHC – requires some modifications in GHC.
- No easy ways to do most basic stuff: Moving terms around(substitutions), known-case reduction, case-of-case, etc. (all done in some parts of Core-to-Core passes, need to reverse engineer)
- No easy way to annotate Core syntax. Duplicating the syntax means duplicating huge amounts of code.
- Working on Core is hard: Invariants are encoded as partial functions without any helpful error messages – if we're lucky, there's a NOTE.
- Some things are not clear. (Types are first-class, but can I use them wherever I want? The Core definition allows this)

# 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?
  - Are profile-driven decision making possible?
  - Are machine learning algorithms applicable?

# Thanks!

Github: [osa1/sc-plugin](#)

IRC: osa1

Email me your slow programs: [oagacan@indiana.edu](mailto:oagacan@indiana.edu)



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