SMART LOOP BREAKER CHOICE

Haskell Implementors Workshop 2011 - Tokyo

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Hello

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Thesis supervised by Atze Dijkstra + Hans Bodlaender

Software Technology

- Functional Programming
- Compilers (UHC)
- Optimisation

Algorithms

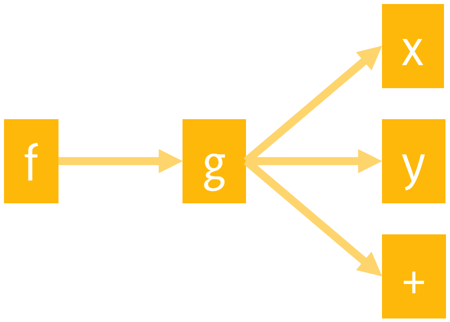
- Big Oh's
- Math
- NP-Completeness
- Fixed Parameter Tractability
- Treewidth


LOOP BREAKING
LIKE A BOSS

Inlining looking like a graph

f = g

g = x + y



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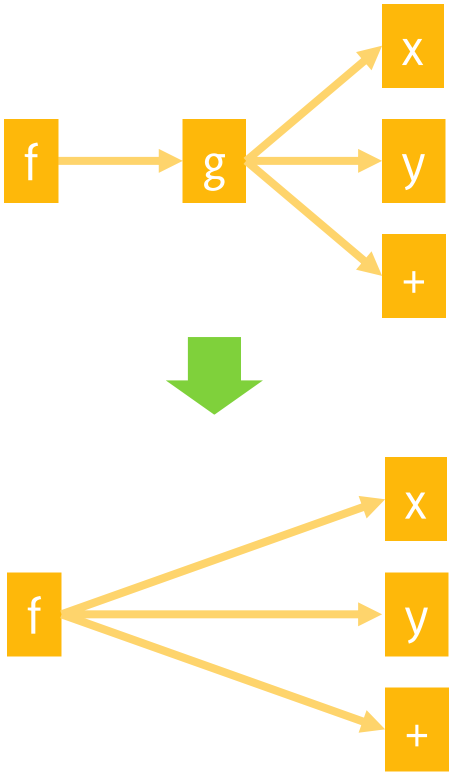

```haskell
map f []     = []
map f (x:xs) = f x : map f xs
```

map f []   = []

map f (x:xs) = f x : **map** f xs

map f []   = []

map f (x:xs) = f x : (case xs of [] -> [];
y:ys -> f y : **map** f ys) f xs

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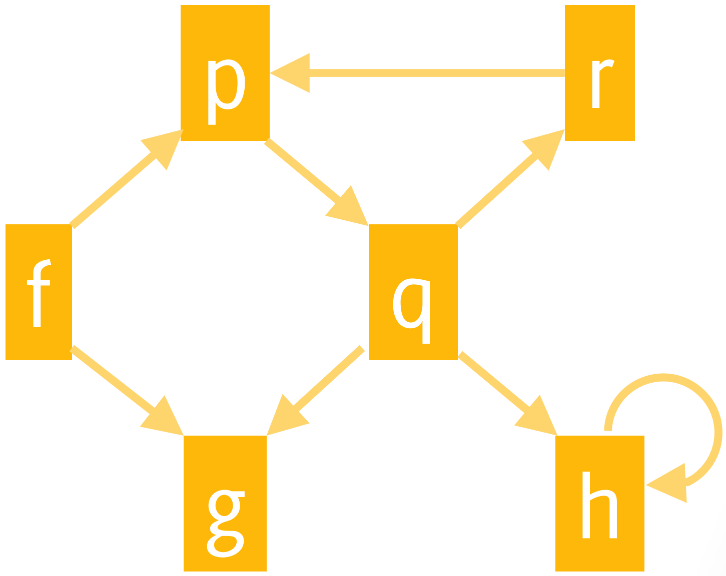
Loop breakers

- Choose a breaker on every loop
- Don't inline loop breakers



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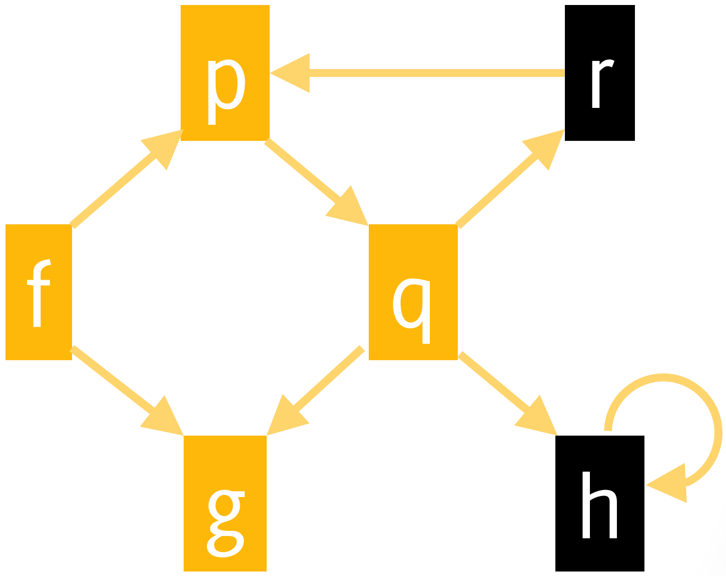

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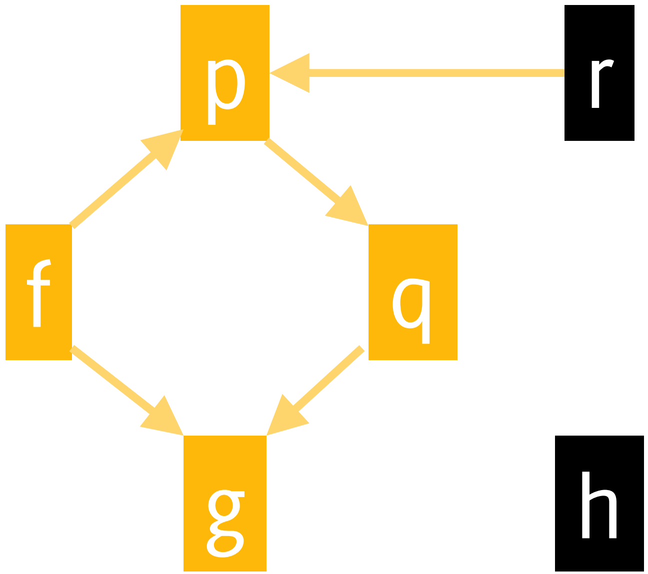
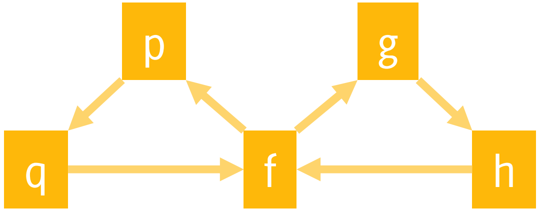


Loop breakers



Goals

- Don't break variables that would be **nice** to inline
- Pick as **few** loop breakers as possible

GHC loop breaker heuristic

1. Decompose into strongly connected components
2. For each component with a cycle:
   A. Pick a node and make it a loop breaker
   B. If still cyclic, repeat from step 1

- Don't pick a node with score n if nodes with score $< n$ are still available
- For each score: after 2 random picks just make all nodes of that score loop breaker

So, the loop breaker heuristic...

Can we do better?

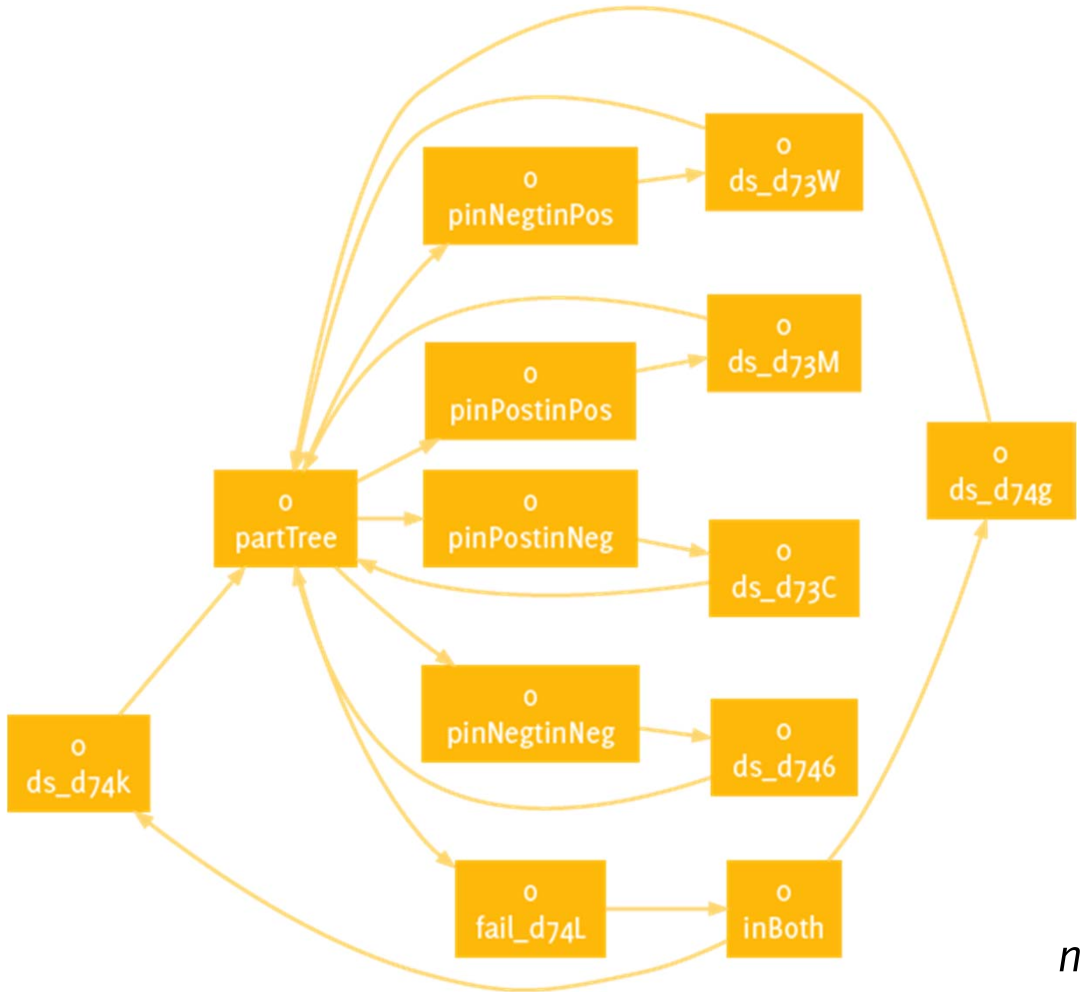
Can we do so quickly?

Do programs actually benefit?

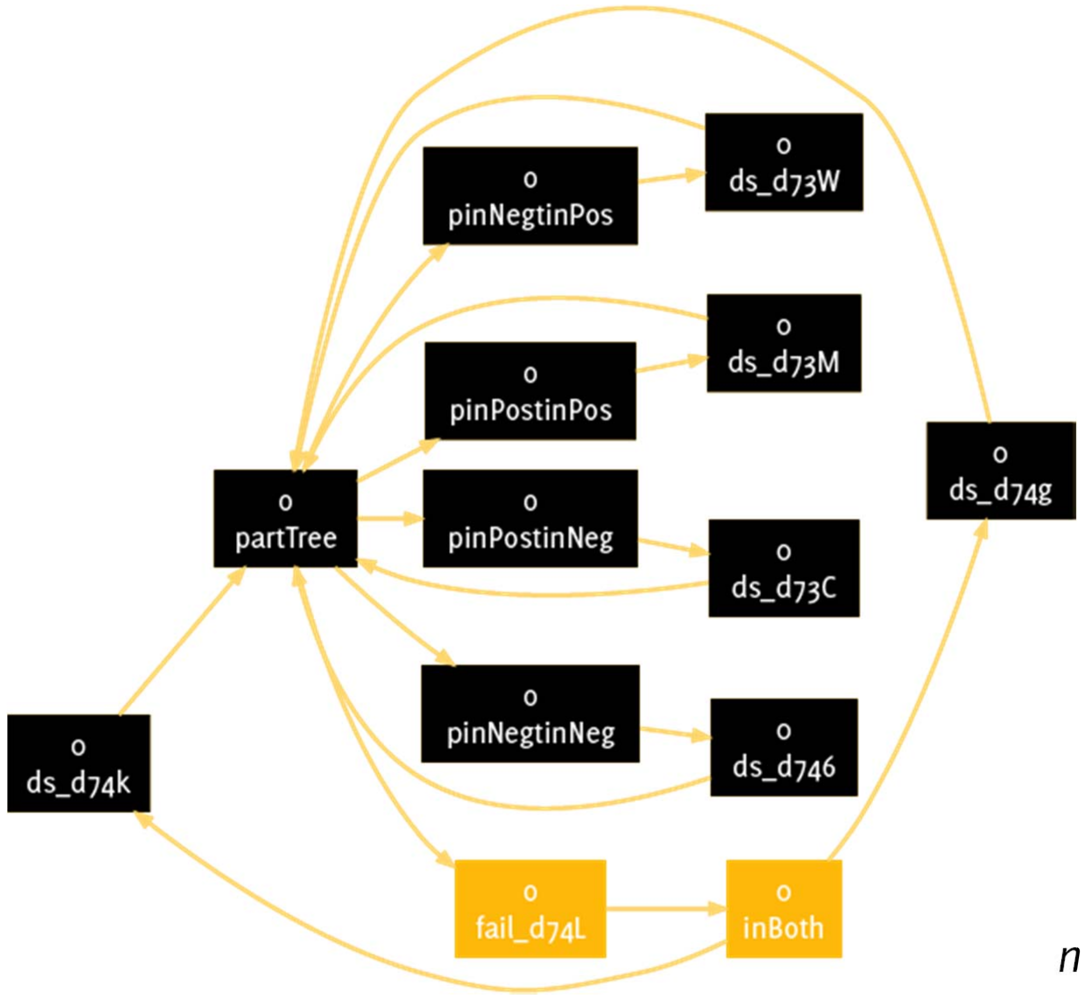
The $\overbrace{}^{\text{blackout}}$ Feedback Vertex Set
directed

In the mathematical discipline of graph theory, a feedback vertex set of a graph is a set of vertices whose removal leaves a graph without cycles.
- *Wikipedia*

- Applications in deadlock-mitigation, chip-design…
- NP-Complete



nofib/real/bspt



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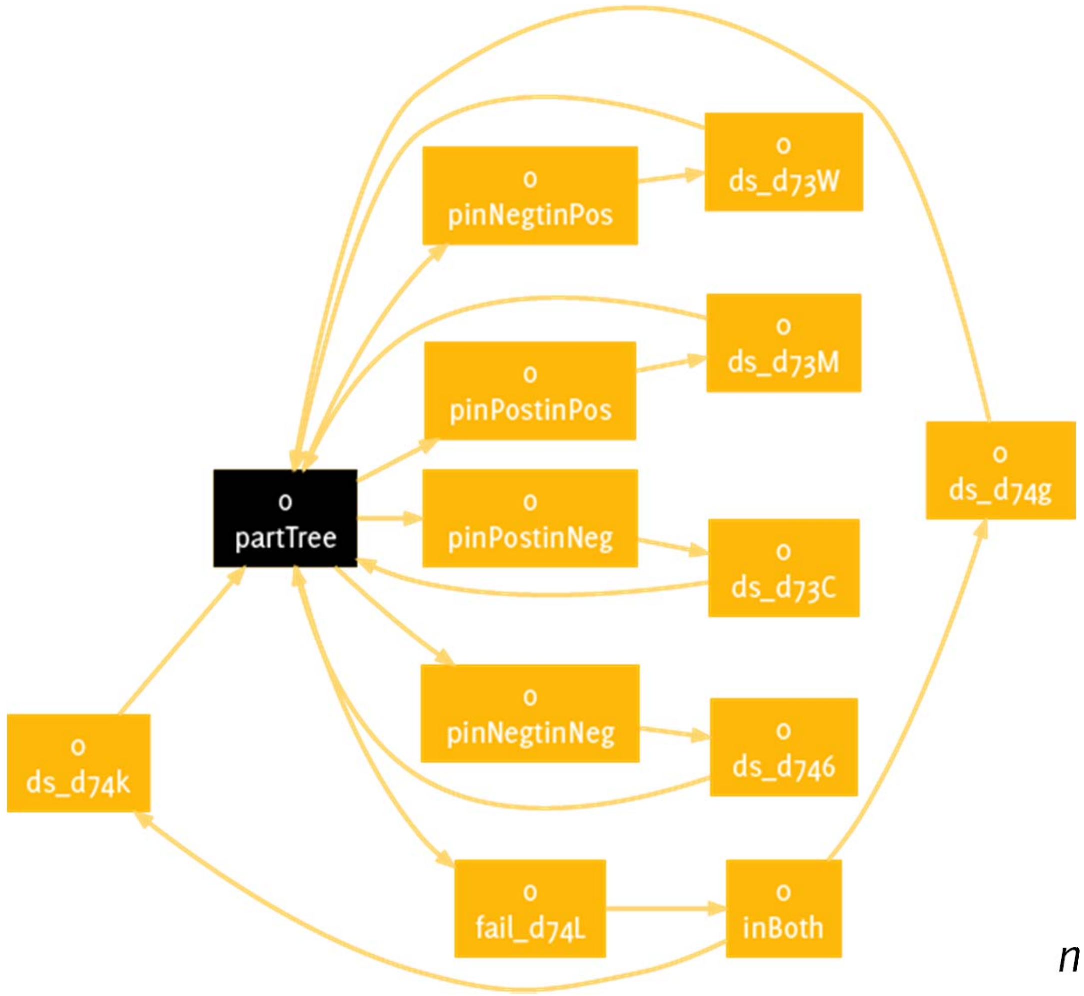

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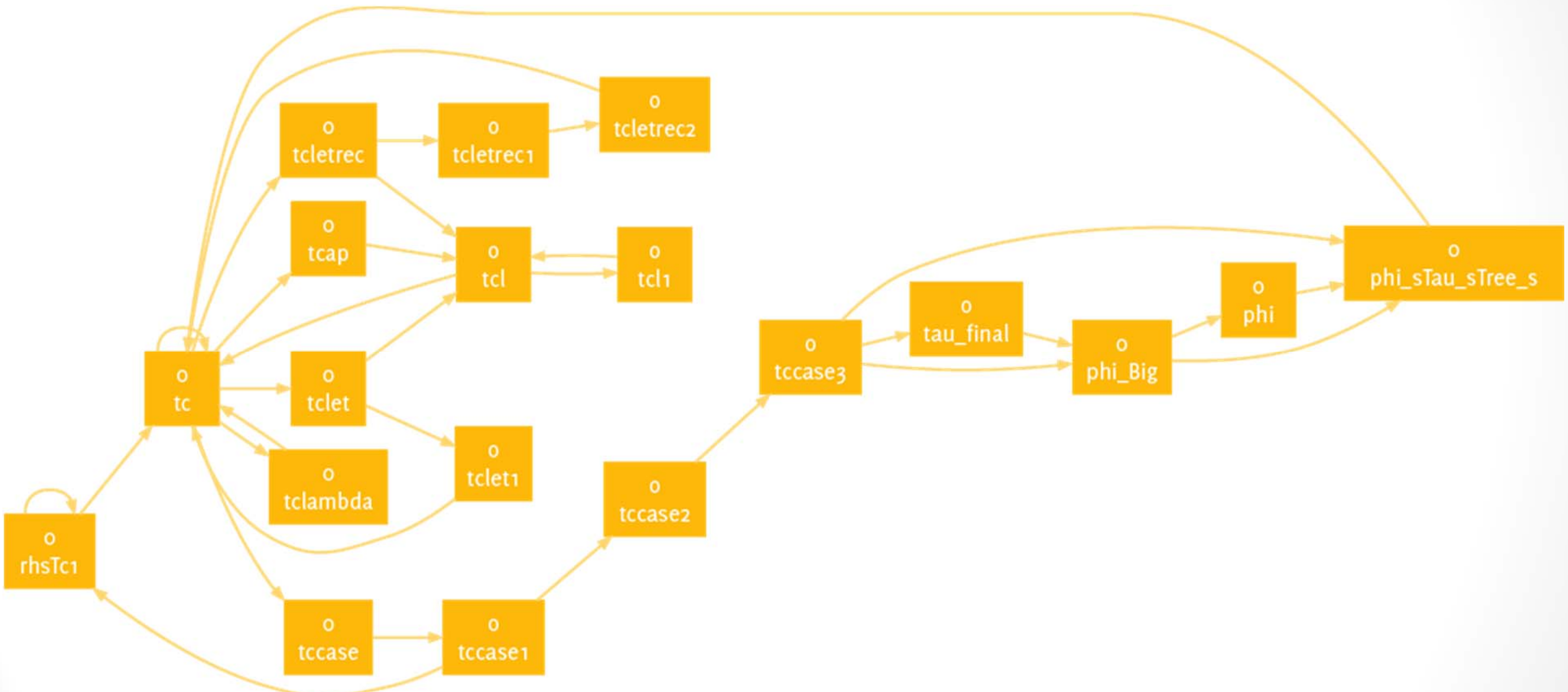
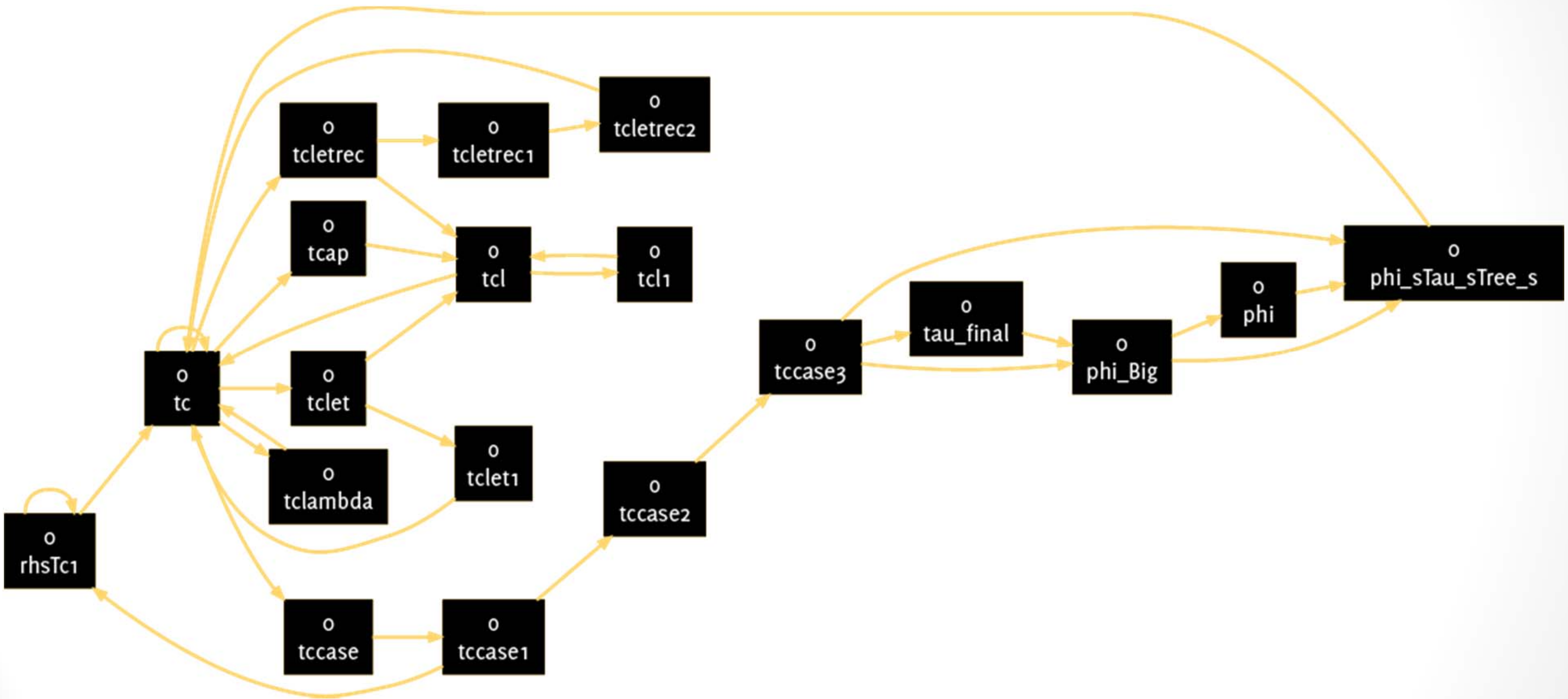


nofib/real/anna



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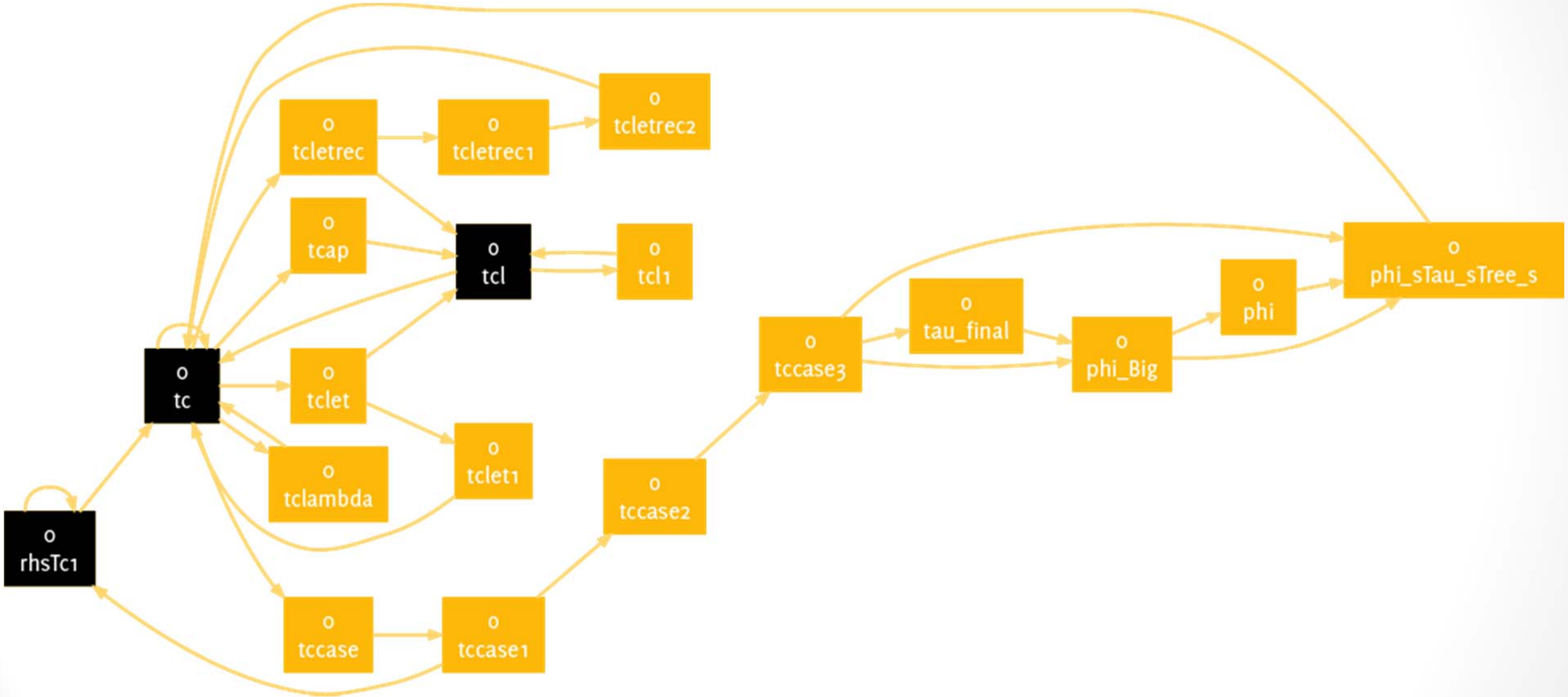

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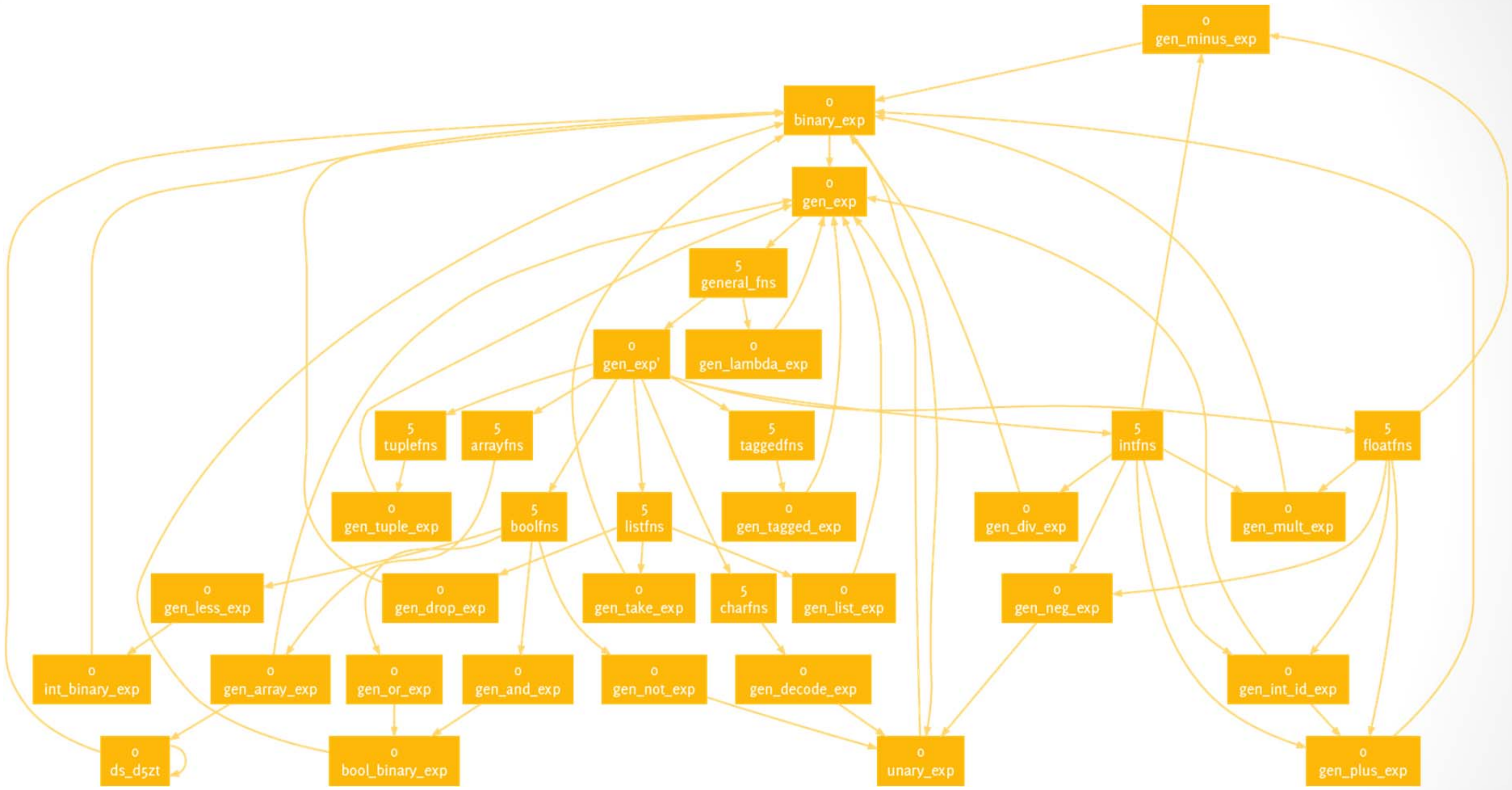
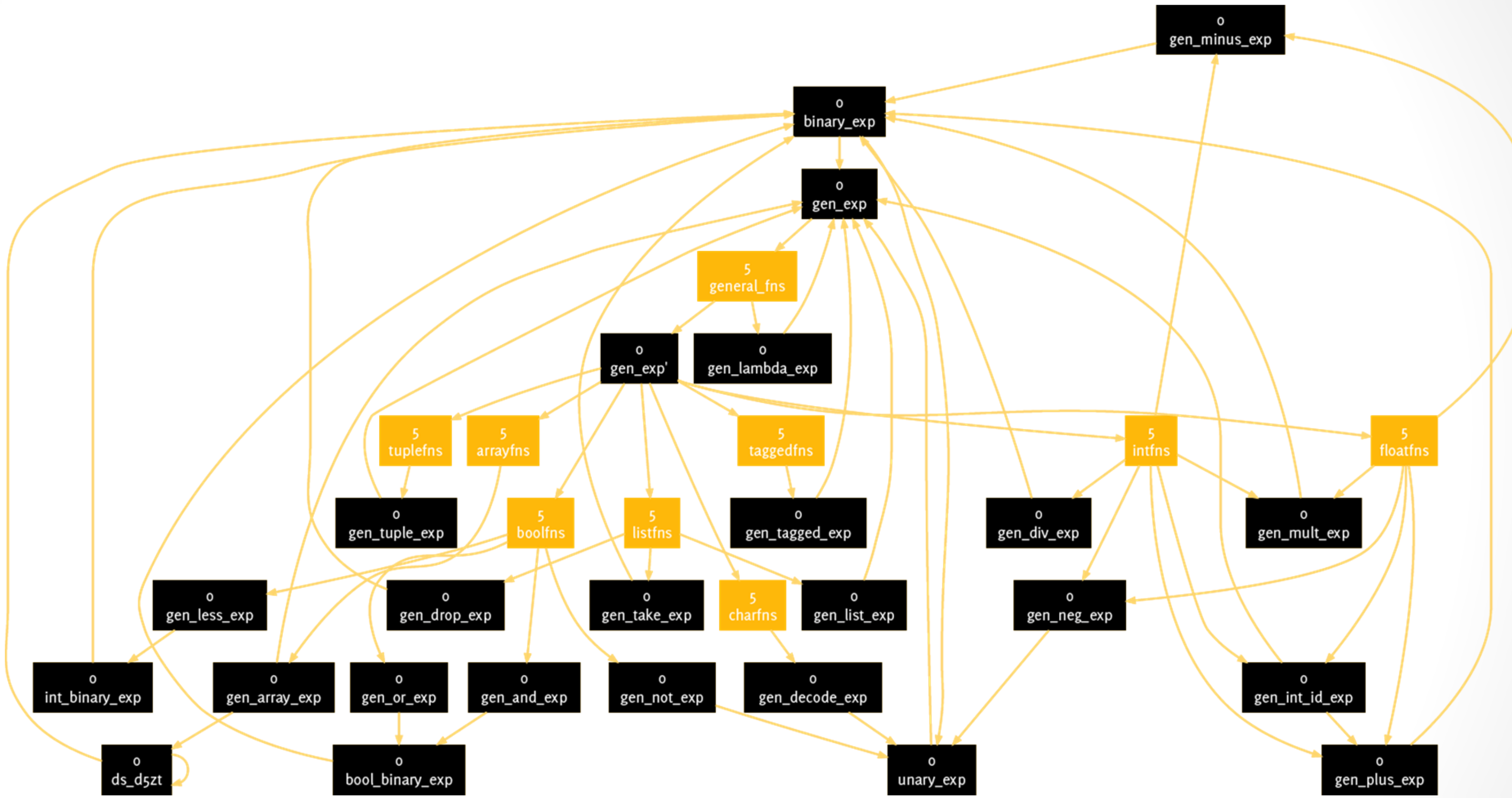


nofib/real/hpg



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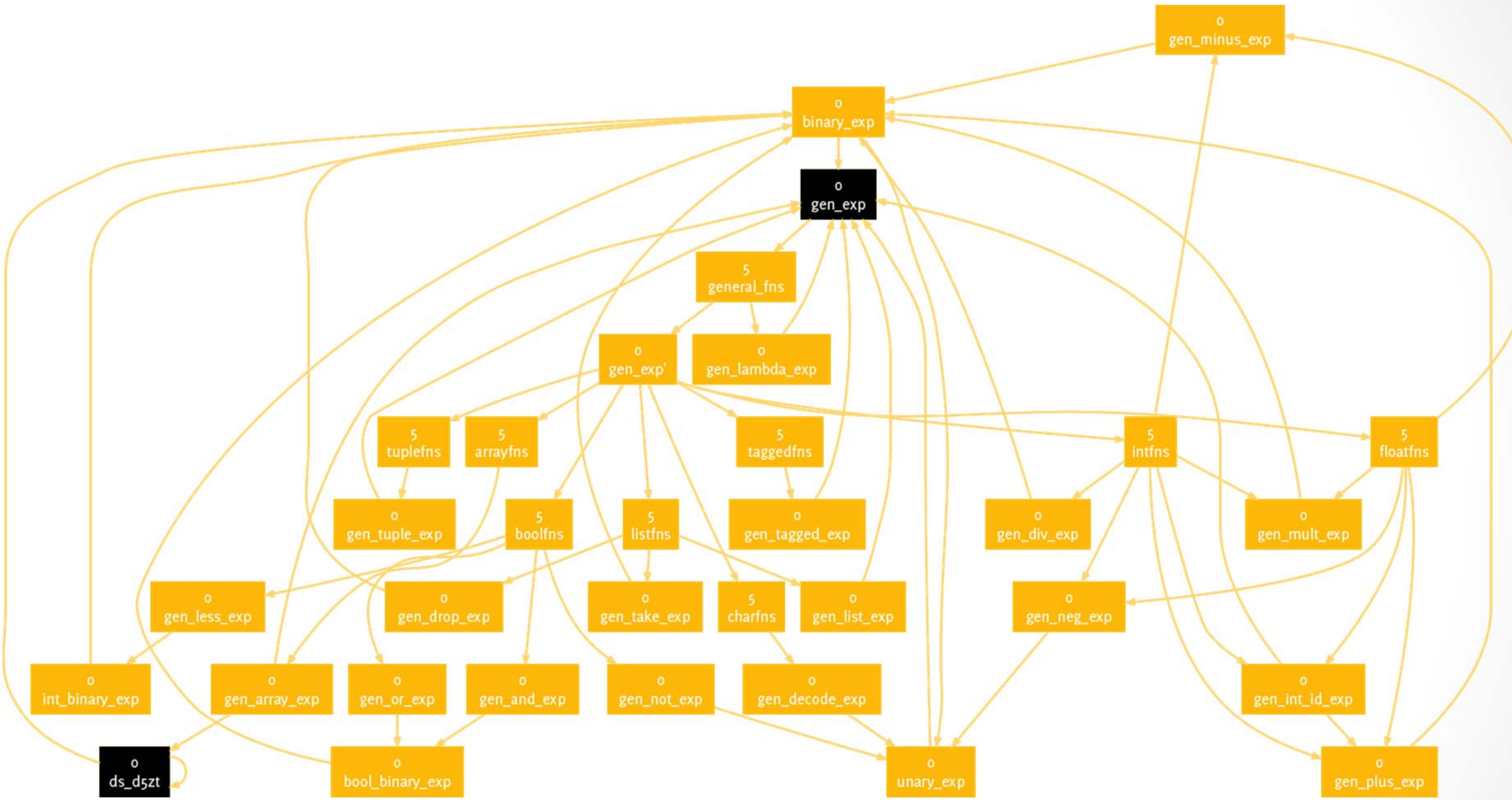

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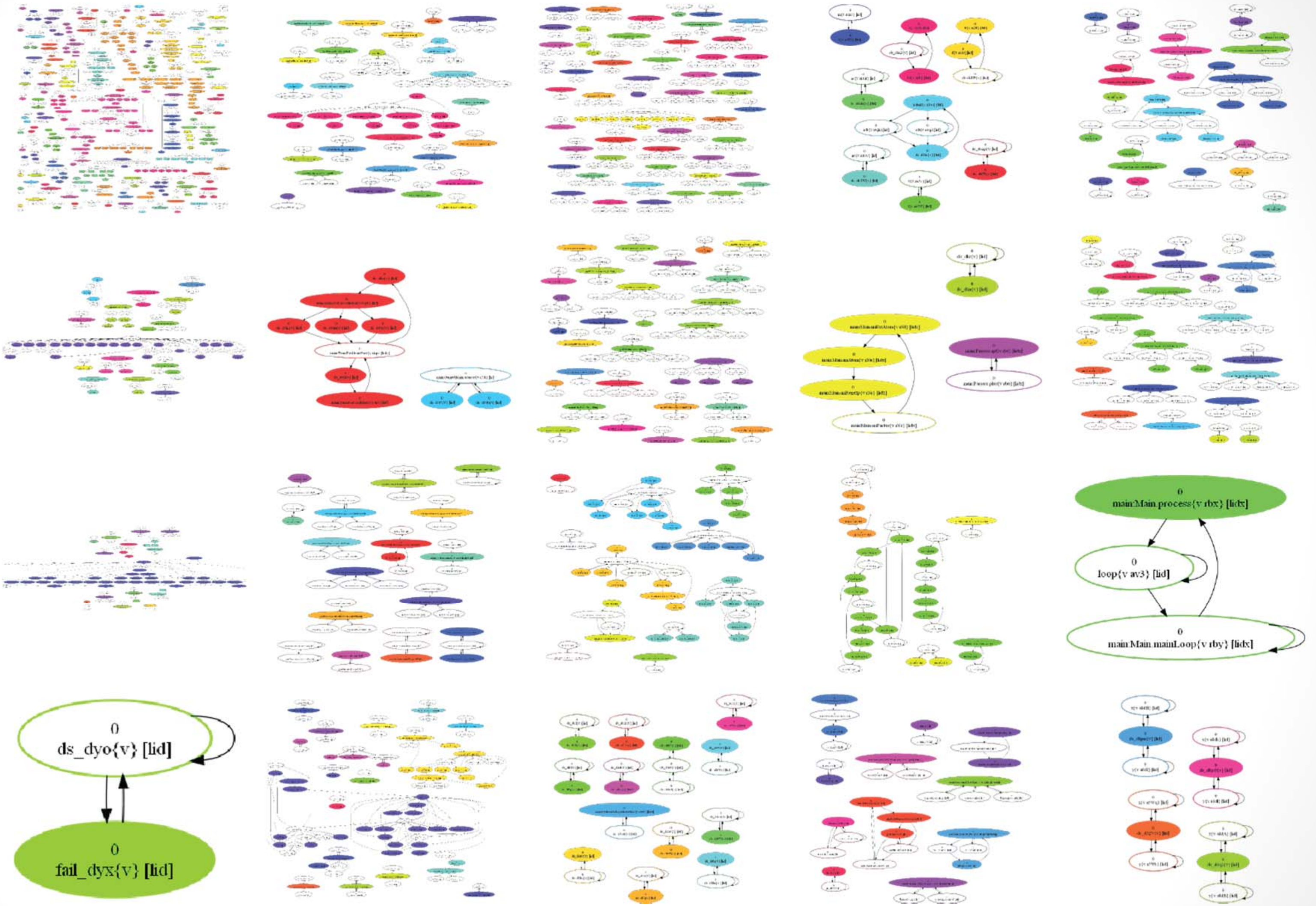
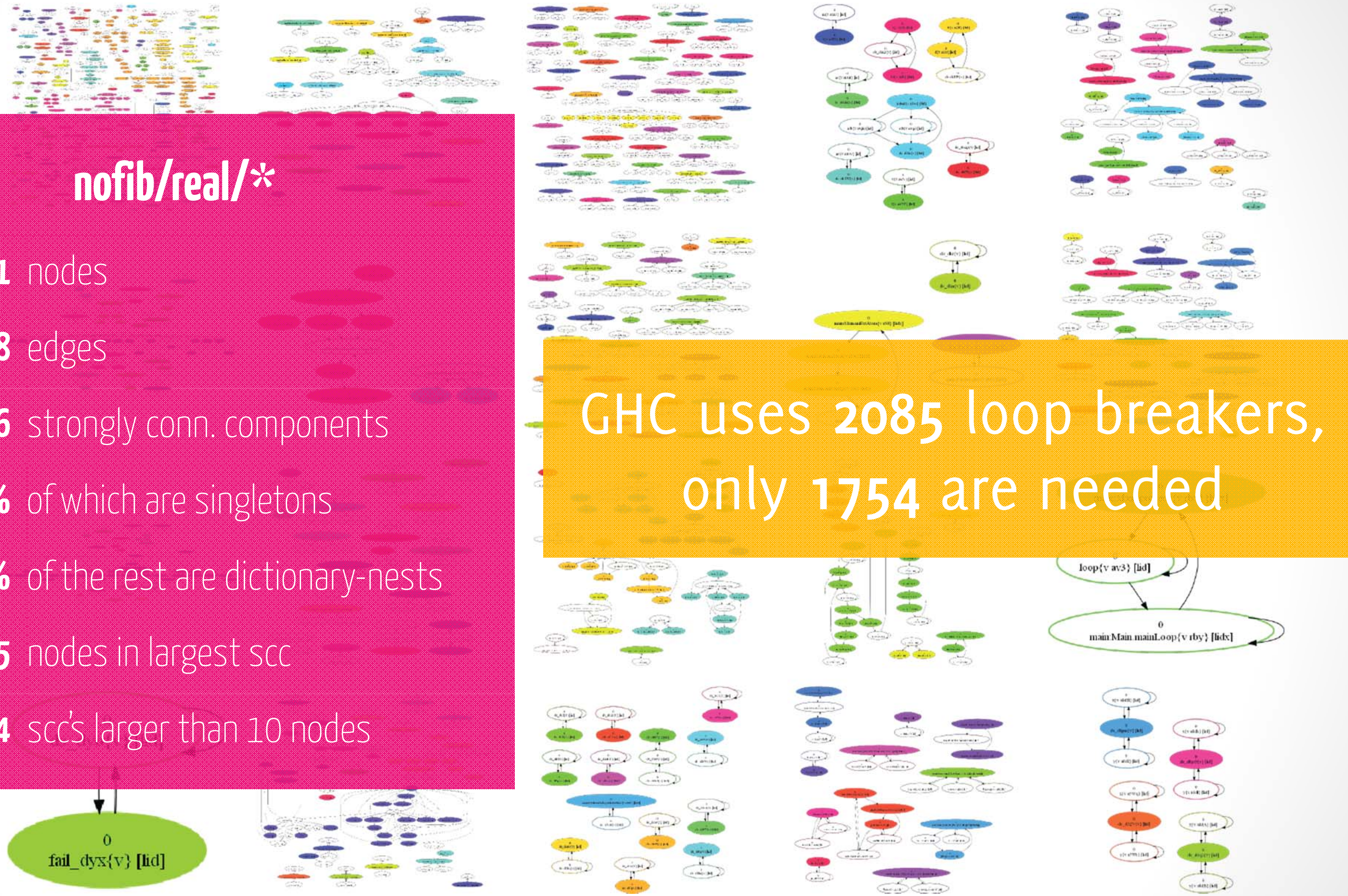

0
main:Main.process{v rbx} [lidx]
0
loop{v av3} [lid]
0
main:Main.mainLoop{v rby} [lidx]
0
ds_dyo{v} [lid]
0
fail_dyx{v} [lid]



nofib/real/*

30491 nodes

98218 edges

29066 strongly conn. components

98% of which are singletons

52% of the rest are dictionary-nests

85 nodes in largest scc

24 scc's larger than 10 nodes

GHC uses **2085** loop breakers, only **1754** are needed

So, the loop breaker heuristic…

Can we do better? Yes

Can we do so quickly?

Do programs actually benefit?

The exact algorithm

1. Split up in SCCs (strongly connected components)
2. Do the *priowiggle* to convert scores to blacked out nodes
3. Apply a few reduction rules
4. **Branch & bound**

The priowiggle

- Goal: black out nodes (make non-breaker) of high score, while making sure that it's still possible to break all cycles

1. Find the lowest score s such that breaking every node with score $\leq s$ results in an acyclic component
2. Black out all nodes with score $> s$

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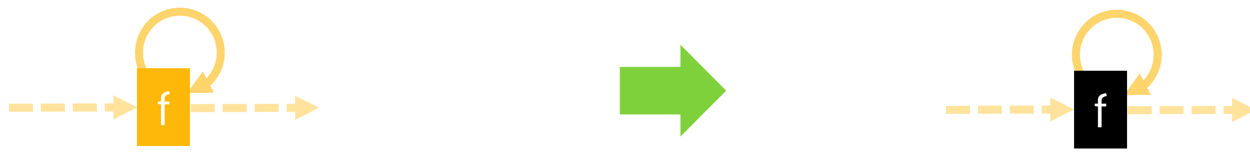
Reduction rules

- Remove duplicate edges
- Keep splitting into SCCs
- Break self-loops



- Shortcut degree two

- Fix non-breaker cycles

- Remove duplicate edges
- Keep splitting into SCCs
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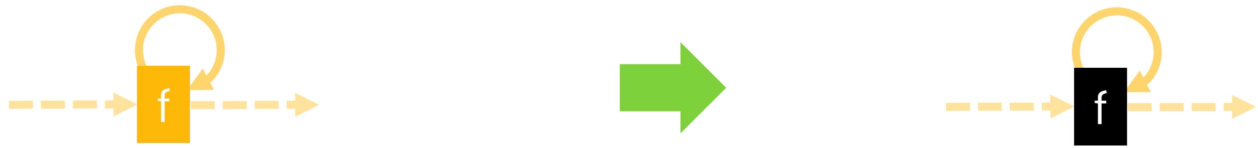

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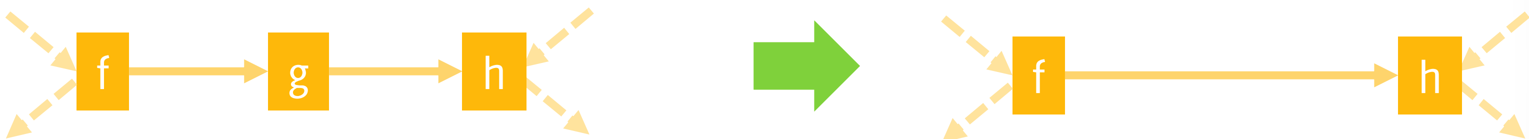

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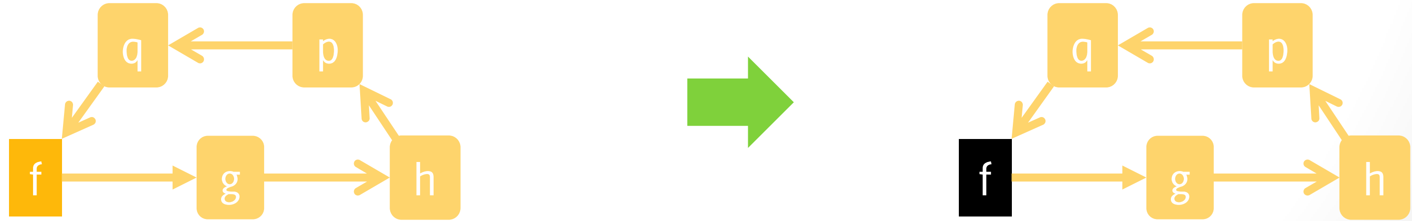
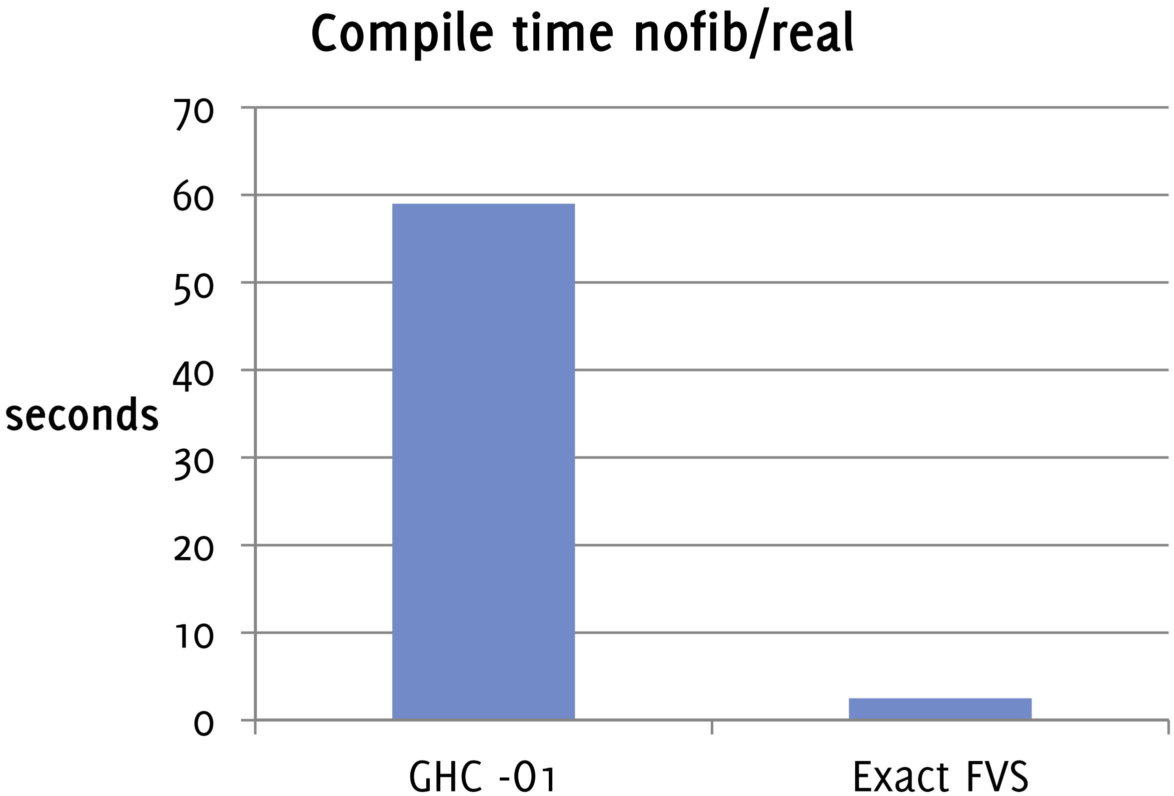



Compile time nofib/real
seconds
70
60
50
40
30
20
10
0
GHC -O1
Exact FVS

So, the loop breaker heuristic...

Can we do better? **Yes**

Can we do so quickly? **Yes**

Do programs actually benefit?

nofib-analyse

- mode=slow
- -O1
- 25 runs

	Size	Allocs	Runtime	Elapsed	TotalMem
Min	-0.0%	-4.9%	-6.4%	-6.5%	+0,0%
Max	+0.1%	+0.0%	+1.5%	+3.0%	+0.0%
Geometric mean	+0.0%	**-0.1%**	**-0.4%**	-0.0%	-0.0%

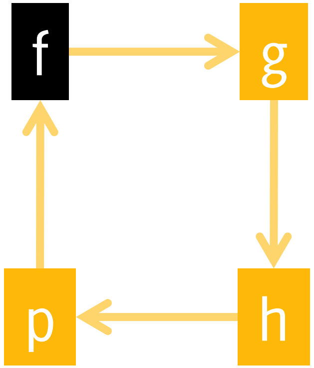
What's going on here?

- Maybe loop breaker choice isn't important
  - More opportunities, but inliner ignores them (make more aggressive?)
- Blame the benchmark
  - Tests are small: 48/91 programs take less than 200 ms, are ignored in totals
  - Maybe improved components are not covered much by tests
- Untested advantages
  - More flexible scoring possible: not just priorities but real scores (for example from a profile)

So, the loop breaker heuristic…

Can we do better?	Yes
Can we do so quickly?	Yes
Do programs actually benefit?	No.. not yet

Doing it on the edges



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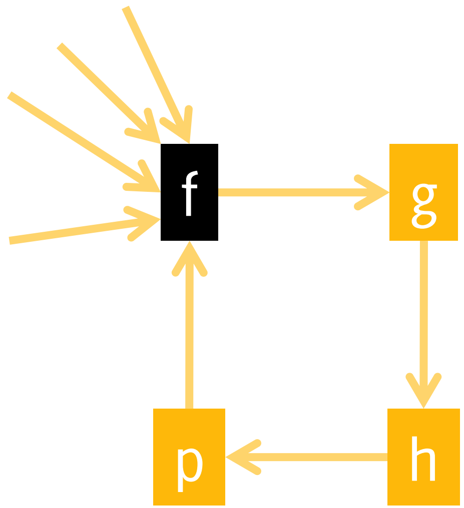


Doing it on the edges

- More accurate portrayal of costs
- Call-site aware
  - Opportunity for more fine-grained scores

5 x = Tree y z

case ? x **of**
    Tree _ _   → a
    Leaf _   → b

- *DFun* special case is no longer necessary

Doing it on the edges

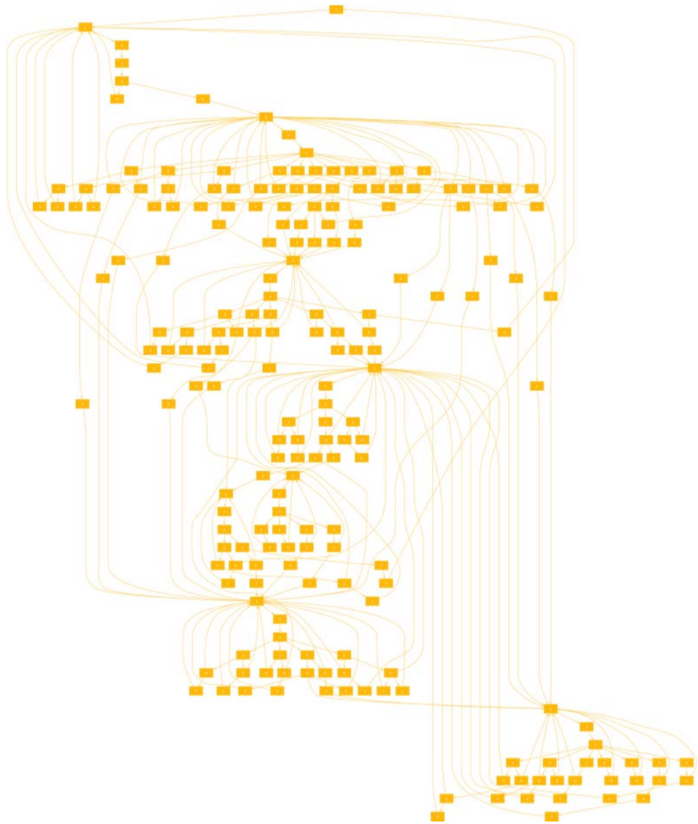
- Blackout feedback **arc** set
- Same trick, slightly different reduction rules

Optimum FAS is **44%** smaller than GHC's heuristic on nofib/real

So, the loop breaker heuristic…

	nodes	edges
Can we do better?	Yes	Yes
Can we do so quickly?	Yes	Yes
Do programs actually benefit?	No.. not yet	??

spectral/boyer



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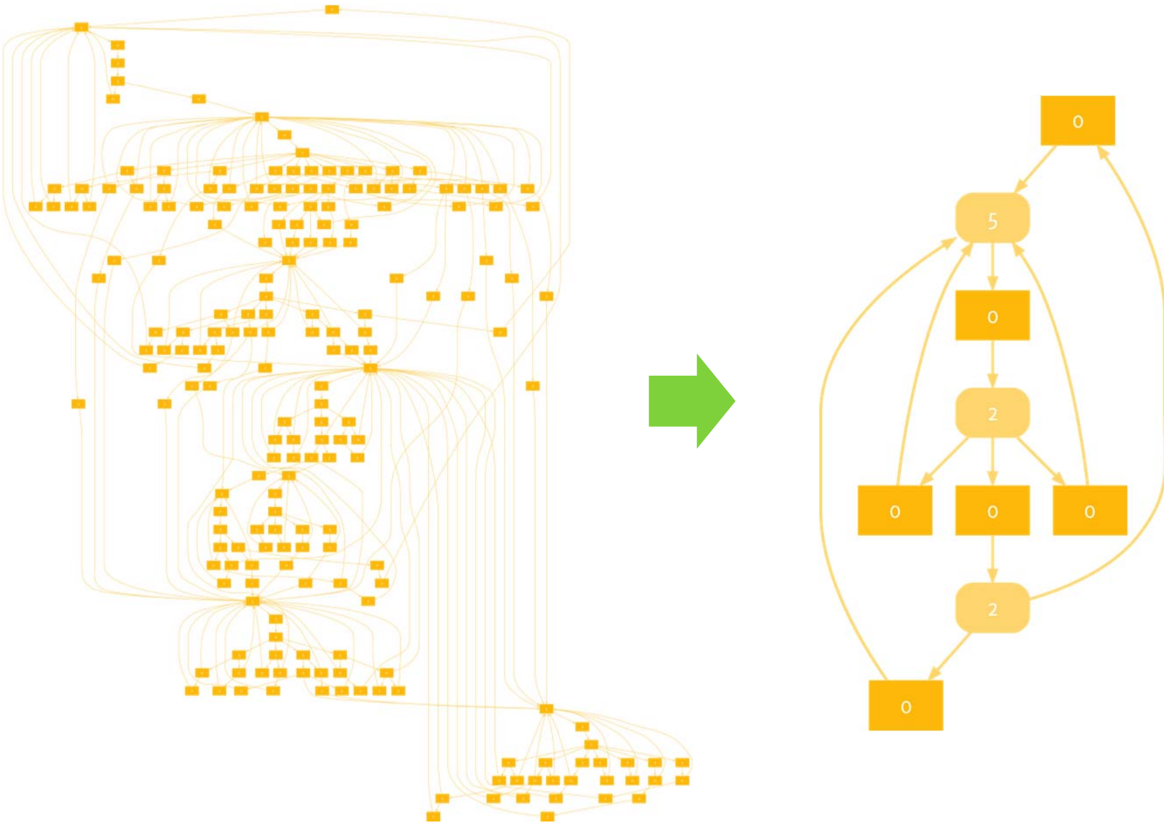

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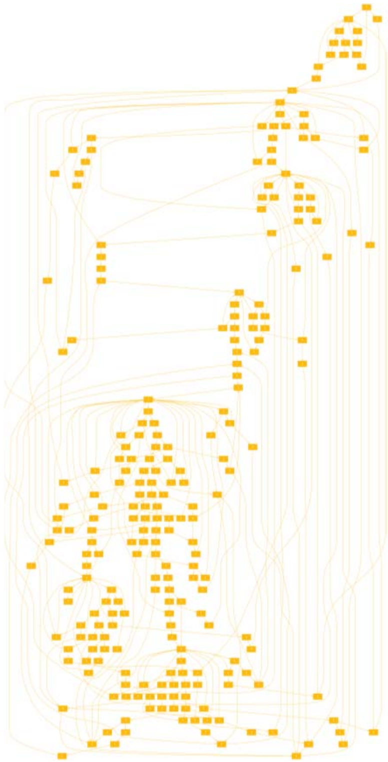

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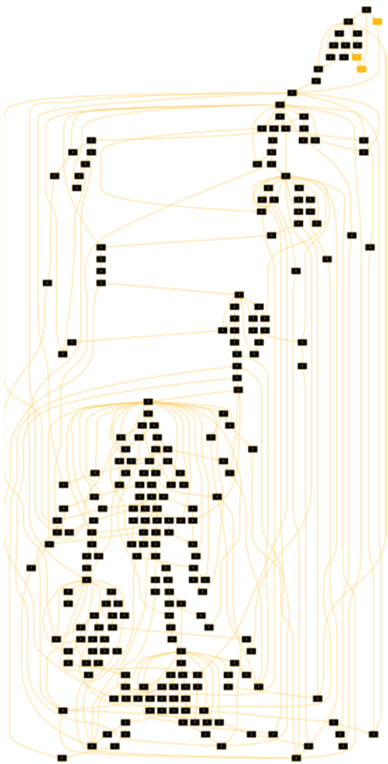

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