Optimizing Signal Graphs for Functional-Reactive Programs

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University of Bonn

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Elm – An FRP Language (`www.elm-lang.org`)

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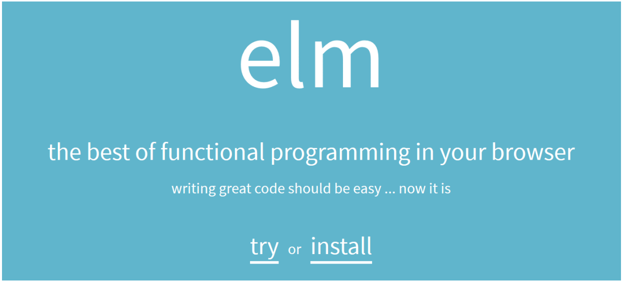

For me, primarily a teaching tool, using it for:

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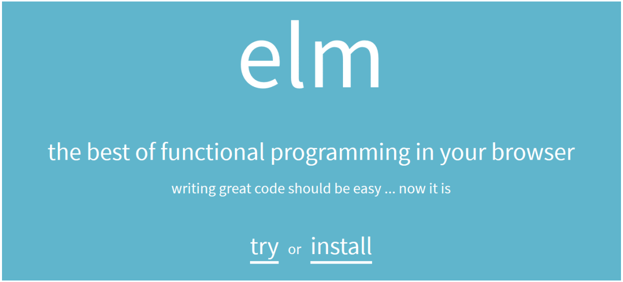

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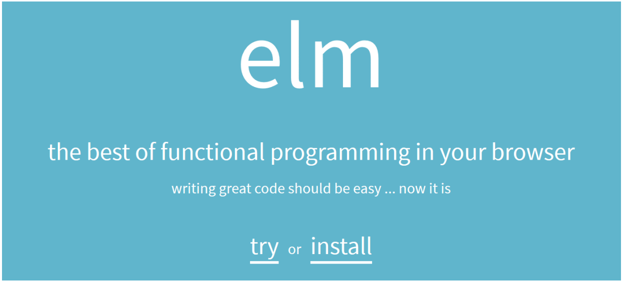

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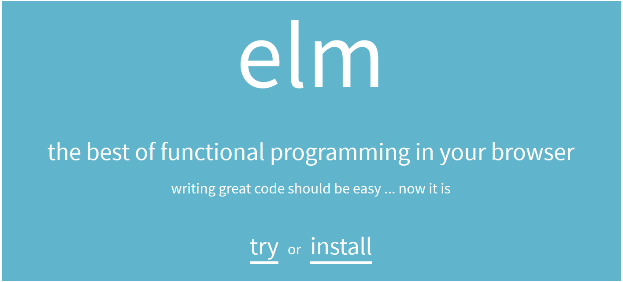

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A Simple Elm Program

Signals ...

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behavior : Signal (Time, (Int, Int))
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main = Signal.map view behavior
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A Simple Elm Program ... and its Signal Graph

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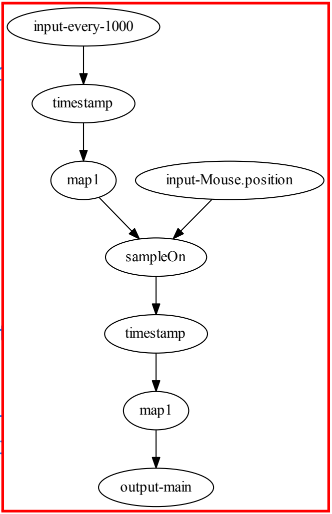
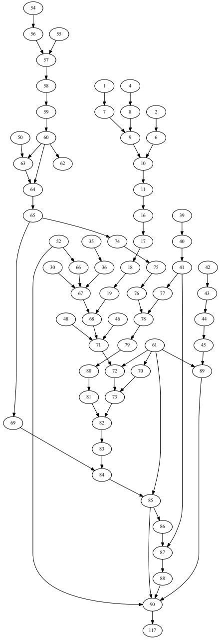


Optimizing Signal Graphs

Why ?

- communication flow
  structure / overhead



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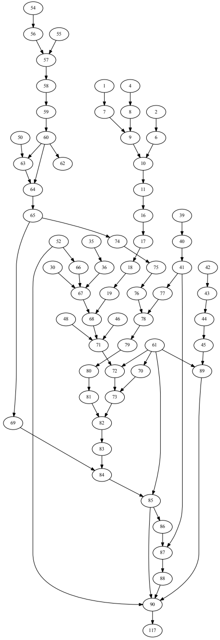

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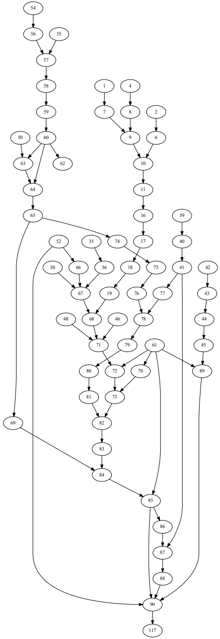

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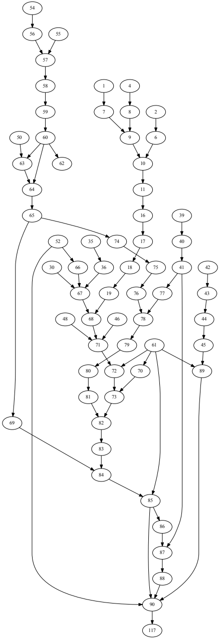
How ?

- as a start, collapse chains of nodes
- by some kind of syntactic fusion ?



Fusion of Signal Primitives

A simple case:

$$\text{Signal.}\texttt{map}\ f\ (\text{Signal.}\texttt{map}\ g\ \textit{signal})$$
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Further candidates:

- Time.`timestamp`
- Signal.`dropRepeats`
- Signal.`filter`
- Signal.`filterMap`
- Signal.`foldp`

Problems with Syntactic Fusion

A not so simple case:

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Actually detecting fusable chains:

$\mathit{signal}_1 = \text{Signal.}\texttt{map}\ g\ \mathit{signal}$
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$\mathit{signal}_2 = \text{Signal.}\texttt{map}\ f\ \mathit{signal}_1$ -- inline signal_1?

$\mathit{signal}_3 = \texttt{do-whatever-with}\ \mathit{signal}_1$ -- what now?

Phase Separation

Fact: Signal graphs in Elm are static (once created).

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The types make it so!

Conceptually, 3 phases in executing an Elm program:

1. compiling Elm to JavaScript;
2. running some JavaScript, setting up the signal graph of nodes, which embed further JavaScript;
3. sending events to the signal graph, running the JavaScript embedded in nodes.

Phase Separation

Signal graph construction: 'red' code.
Pure functions in nodes: 'green' code.

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\end{aligned}$$

$$\texttt{main} = \mathsf{Signal.}\texttt{map}\ \texttt{view}\ \texttt{behavior}$$

And there can be some 'yellow' code as well.

Thus Motivated Optimization Strategy

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1. Wait until all ‘red’ (and maybe some ‘yellow’) JavaScript code has run.
2. Traverse and shrink the signal graph, potentially moving around ‘green’ JavaScript function objects (which might reference ‘yellow’ ones).
   - Create ‘fat nodes’ that do the work of a whole chain of nodes,
   - but that do short-circuit when appropriate (and use iteration instead of function calls).

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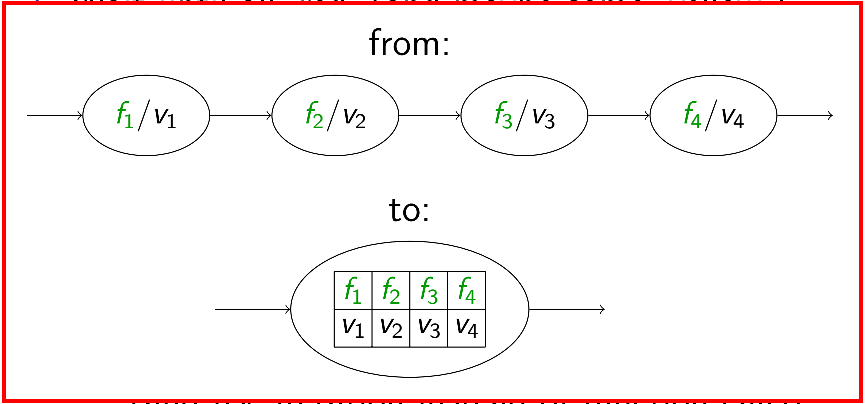

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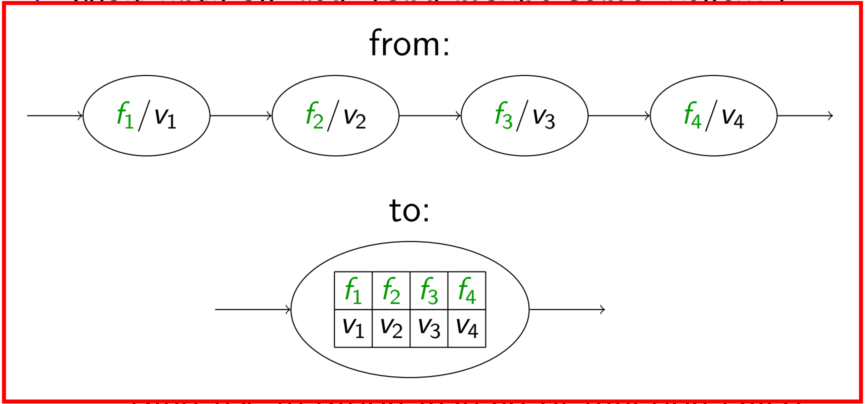

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Sounds easy.

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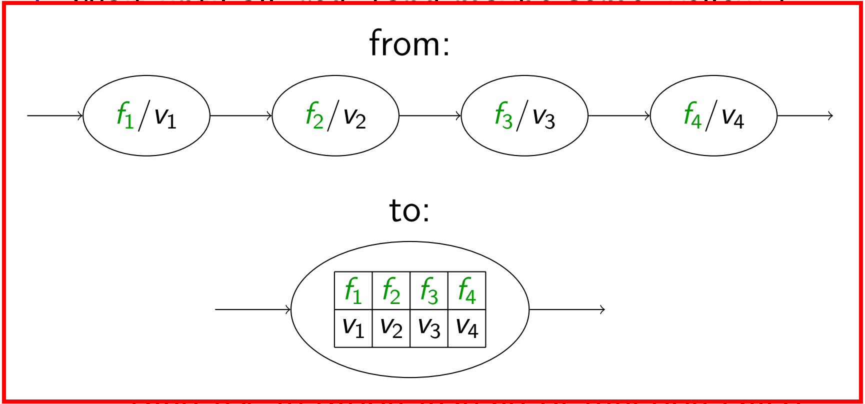

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Sounds easy. Well, yes, but as always the devil is in the details. For example, it turns out JavaScript is an imperative language with mutable state...

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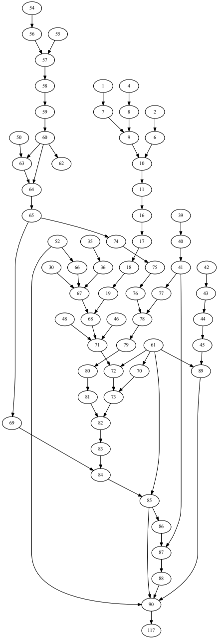

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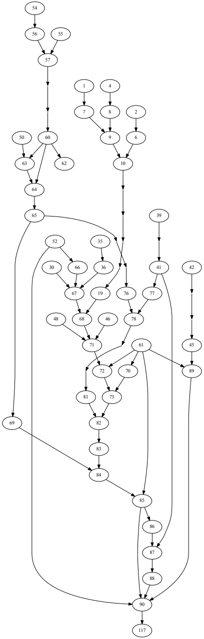

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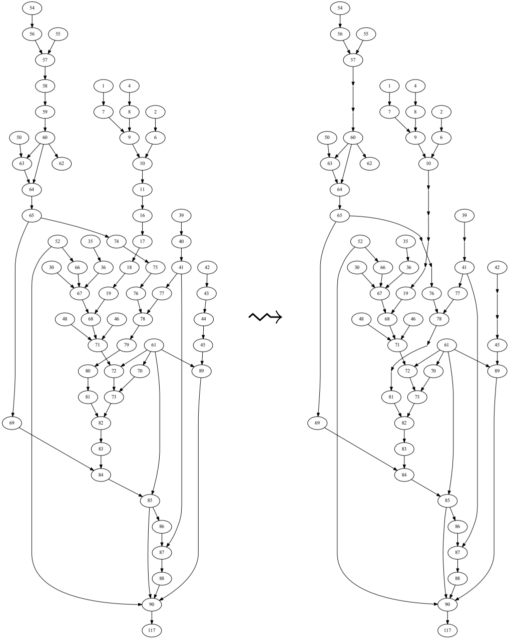

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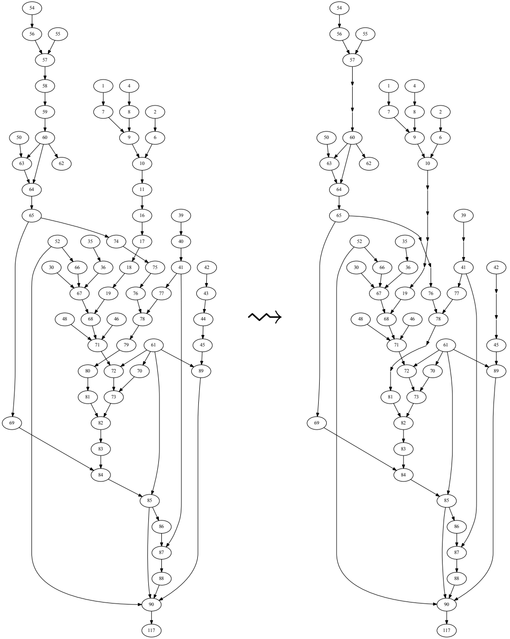

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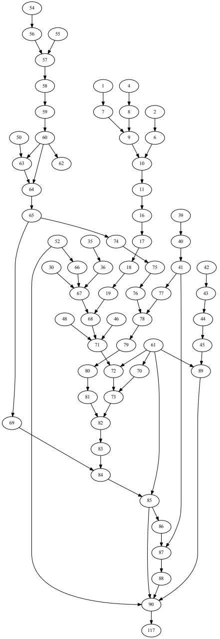

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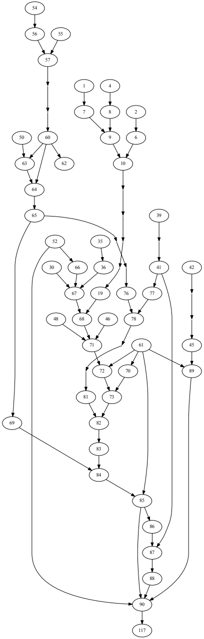

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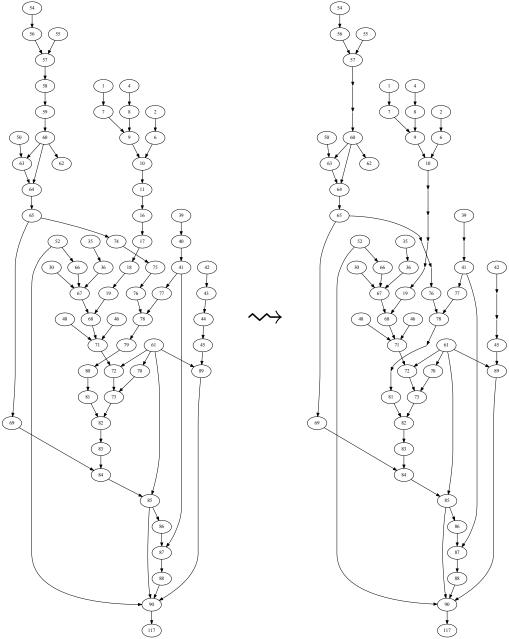

Open:

- evaluate impact on performance (beyond anecdotal)
- impact on debugging, hot-swapping ?
- deeper fusion (of 'green' functions) ?
- other optimizations, . . .