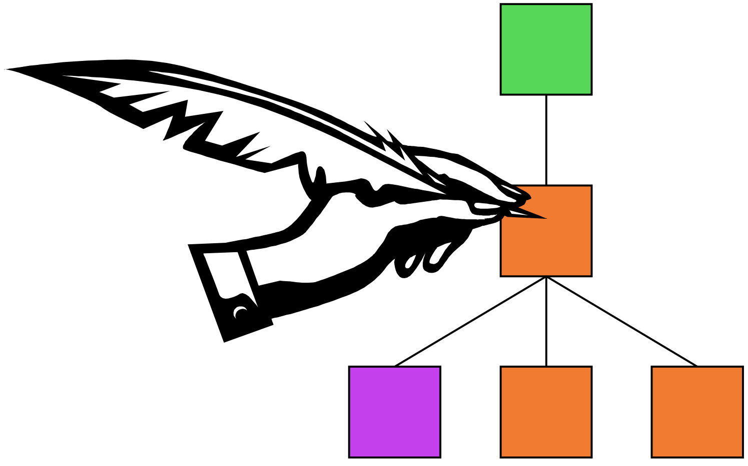
Playing with Haskell Data



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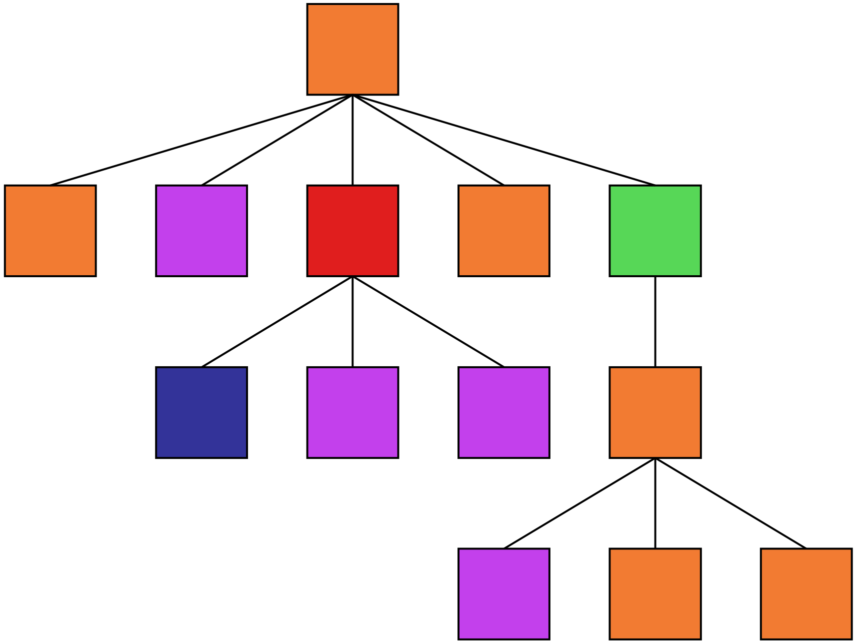
Overview

- The “boilerplate” problem
- Haskell’s weakness (really!)
- Traversals and queries
- Generic traversals and queries
- Competitors (SYB and Compos)
- Benchmarks

λ Data structures

- A tree of *typed* nodes
- Parent/child relationship is important



A concrete data structure

```
data Expr = Val Int
          | Neg Expr
          | Add Expr Expr
          | Sub Expr Expr
```

- Simple arithmetic expressions

Task: Add one to every Val

```
inc :: Expr -> Expr
inc (Val i) = Val (i+1)
inc (Neg x) = Neg (inc x)
inc (Add x y) = Add (inc x) (inc y)
inc (Sub x y) = Sub (inc x) (inc y)
```

- What is the worst thing about this code?

Many things!

1. If we add Mul, we need to change
2. The action is one line, obscured
3. Tedious, repetitive, dull
4. May contain subtle bugs, easy to overlook
5. Way too long

The boilerplate problem

- A lot of tasks:
  1. Navigate a data structure (boilerplate)
  2. Do something (action)
- Typically boilerplate is:
  - Repetitive
  - Tied to the data structure
  - Much bigger than the action

Compared to Pseudo-OO[1]

```
class Expr
class Val : Expr {int i}
class Neg : Expr {Expr a}
class Add : Expr {Expr a, b}
class Sub : Expr {Expr a, b}
```

1) Java/C++ are *way* to verbose to fit on slides!

Inc, in Pseudo-OO

```
void inc(x){
if (x is Val) x.i += 1;
if (x is Neg) inc(x.a)
if (x is Add) inc(x.a); inc(x.b)
if (x is Mul) inc(x.a); inc(x.b)
}
```

Casts, type evaluation etc omitted

λ Haskell's weakness

- OO actually has a lower complexity
  - Hidden very effectively by horrible syntax
- In OO objects are deconstructed
- In Haskell data is deconstructed *and* reconstructed
- OO destroys original, Haskell keeps original

Comparing inc for Add

- Haskell

```
inc (Add x y) = Add (inc x) (inc y)
```

- OO

```
if (x is Add) inc(x.a); inc(x.b)
```

- Both deconstruct Add (follow its fields)
- Only Haskell rebuilds a new Add

λ Traversals and Queries

- What are the common forms of "boilerplate"?
  - Traversals
  - Queries

- Other forms do exist, but are far less common

λ Traversals

- Move over the entire data structure
- Do "action" to each node
- Return a new data structure

- The previous example (inc) was a traversal

Queries

- Extract some information out of the data
- Example, what values are in an expression?

A query

```
vals :: Expr -> [Int]
vals (Val i) = [i]
vals (Neg x) = vals x
vals (Add x y) = vals x ++ vals y
vals (Mul x y) = vals x ++ vals y
```

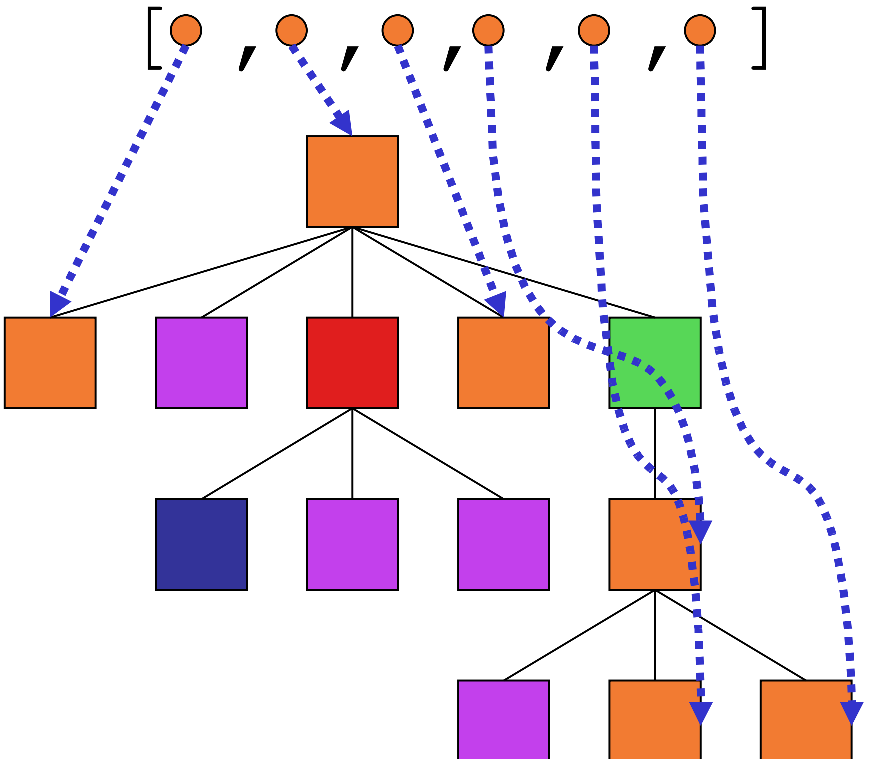
- Same issues as traversals

λ Generic operations

- Identify primitives
  - Support lots of operations
  - Neatly
  - Minimal number of primitives
- These goals are in opposition!
- Here follow my basic operations…

Generic Queries

```
allOver :: a -> [a]
```



λ The vals query

```
vals x = [i | Val i <- allOver x]
```

- Uses Haskell list comprehensions – very handy for queries
- Can anyone see a way to improve on the above?
- Short, sweet, beautiful ☺

More complex query

- Find all negative literals that the user negates:

```
[i | Neg (Val i) <- allOver x
   , i < 0]
```

- Rarely gets more complex than that

Generic Traversals

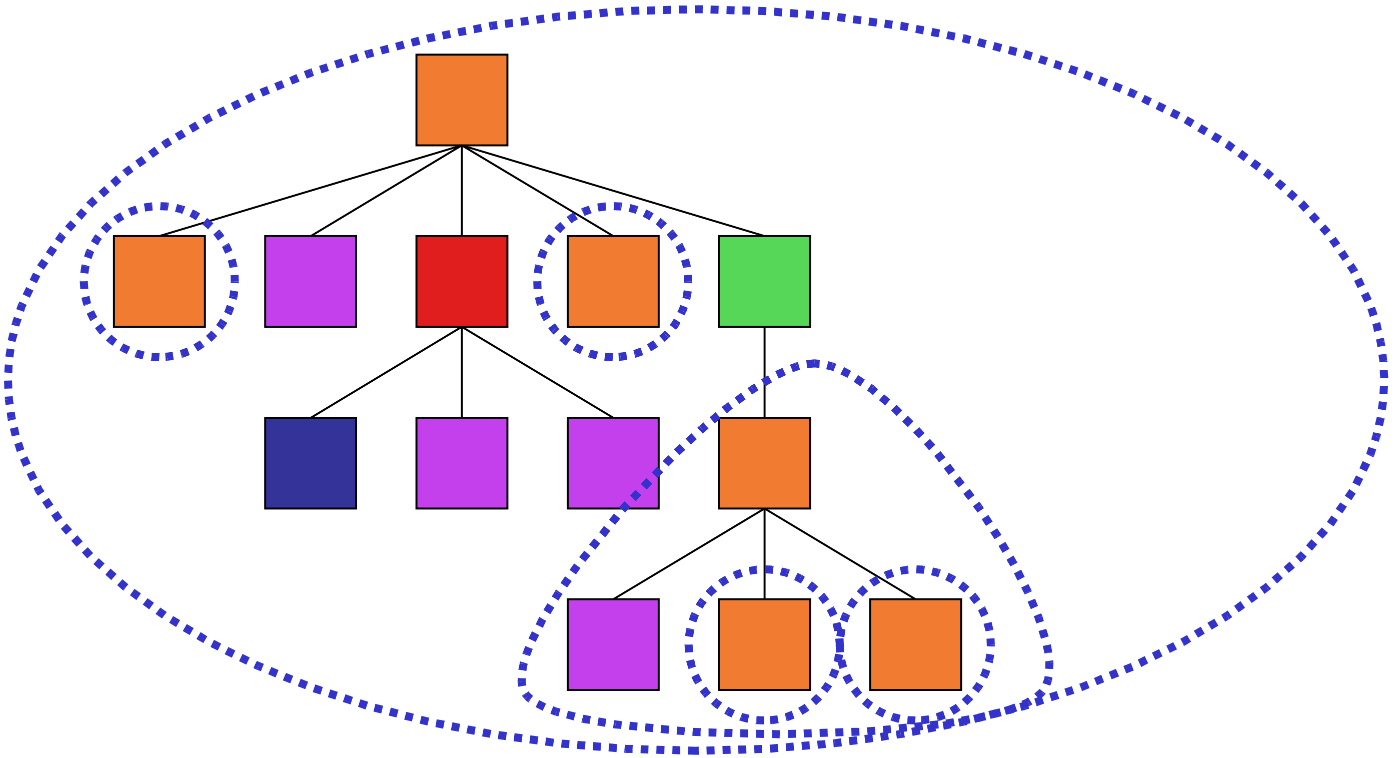
- Have some “mutator”
- Apply to each item

```
traversal :: (a -> a) -> a -> a
```

5. Bottom up
6. Top down – automatic
7. Top down – manual

λ Bottom-up traversal

```
mapUnder :: (a -> a) -> a -> a
```



λ The inc traversal

```
inc x = mapUnder f x
    where
        f (Val x) = Val (x+1)
        f x = x
```

- Say the action (first line)
- Boilerplate is all do nothing

Top-down queries

- Bottom up is almost always best
- Sometimes information is pushed down
- Example: Remove negation of add

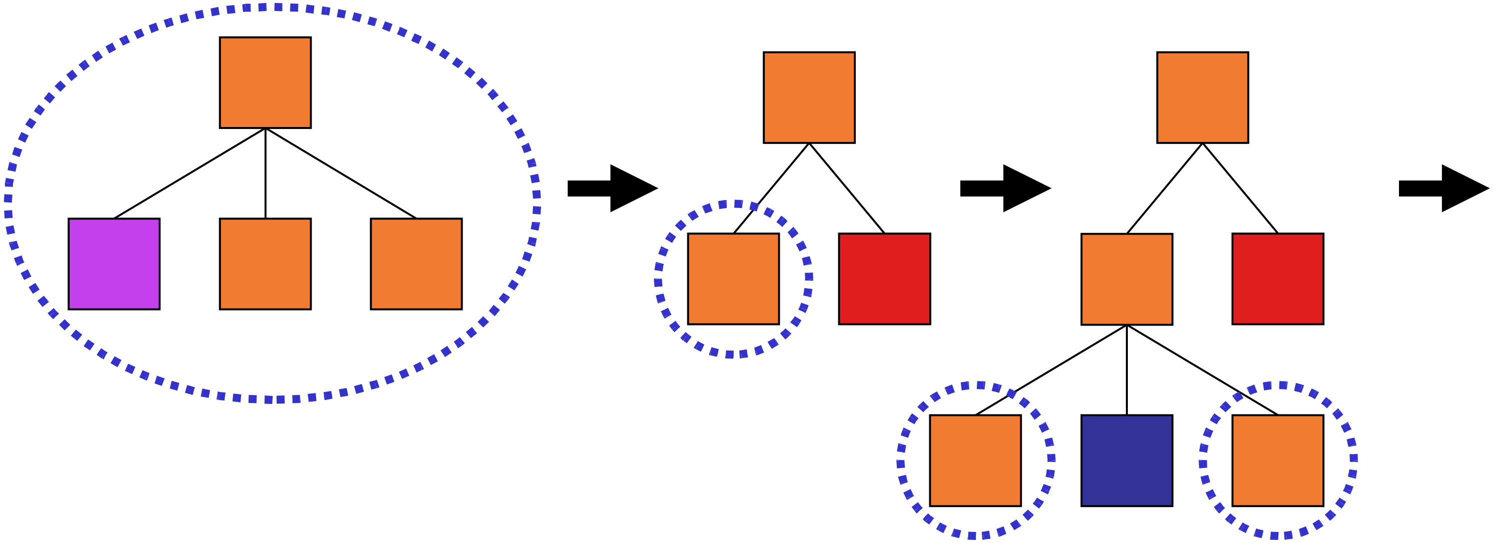
```
f (Neg (Add x y)) = Add (Neg x) (Neg y)
```

- Does not work, x may be Add

```
f (Neg (Add x y)) =
            Add (f (Neg x)) (f (Neg y))
```

Top-down traversal

```
mapOver :: (a -> a) -> a -> a
```



Produces one element per call

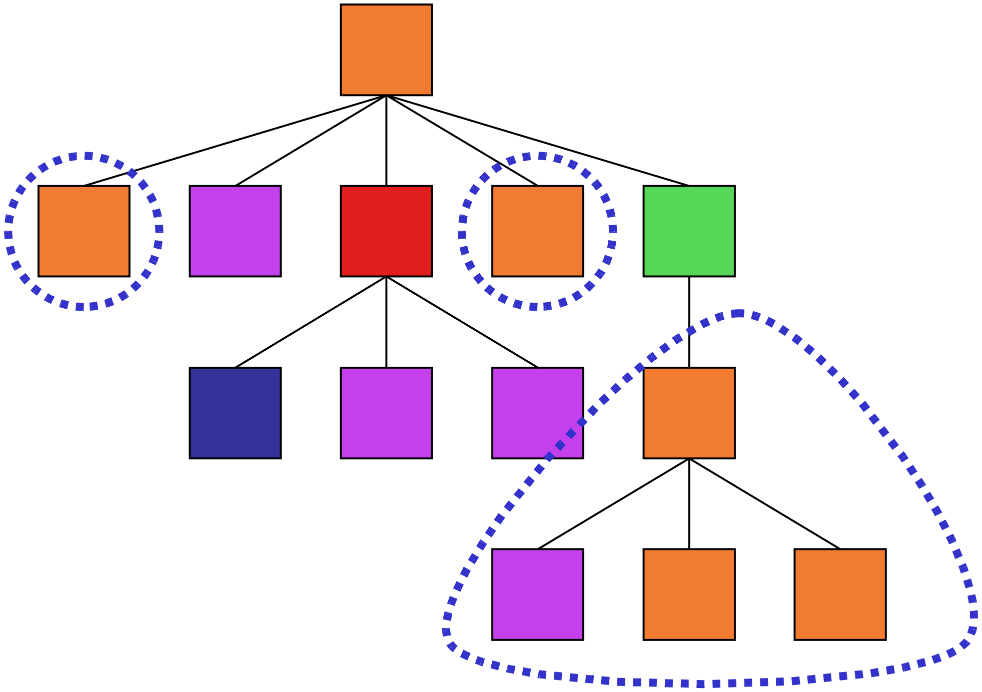
λ One element per call?

- Sometimes a traversal does not produce one element
- If zero made, need to explicitly continue
- In two made, wasted work

- Can write an explicit traversal

Top-down manual

```
compos :: (a -> a) -> a -> a
```



Compos

```
noneg (Neg (Add x y)) =
    Add (noneg (Neg x)) (noneg (Neg y))
noneg x = compos noneg x
```

- Compos does no recursion, leaves this to the user
- The user explicitly controls the flow

Other types of traversal

- Monadic variants of the above

- `allOverContext :: a -> [(a, a -> a)]`
  - Useful for doing something once

- `fold :: ([r] -> a) -> (x -> a -> r) -> x -> r`
  - mapUnder with a different return

The Challenge

Pick an operation

Will code it up “live”

Traversals for *your* data

- Haskell has *type classes*
- `allOver :: Play a => a -> [a]`

- Each data structure has its own methods
- allOver Expr /= allOver Program

Minimal interface

- Writing 8+ traversals is annoying
- Can define all traversals in terms of one:

```
replaceChildren :: x -> ([x], [x] -> x)
```

- Get all children
- Change all children

λ Properties

```
replaceChildren :: x -> ([x], [x] -> x)
(children, generate) = replaceChildren x
```

- generate children == x
- @pre generate y

  length y == length children

Some examples

```
mapOver f x = gen (map (mapOver f) child)
where (child,gen) = replaceChildren (f x)

mapUnder f x = f (gen child2)
where (child,gen) = replaceChildren x
      child2 = map (mapUnder f) child

allOver x = x : concatMap allOver child
Where (child,gen) = replaceChildren x
```

Writing replaceChildren

- A little bit of thought
- Reasonably easy

- Using GHC, these instances can be derived automatically

λ Competitors: SYB + Compos

- Not Haskell 98, GHC only
- Use scary types…

- Compos
  - Provides compos operator and fold
- Scrap Your Boilerplate (SYB)
  - Very generic traversals

Compos

- Based on GADT's
- No support for bottom-up traversals

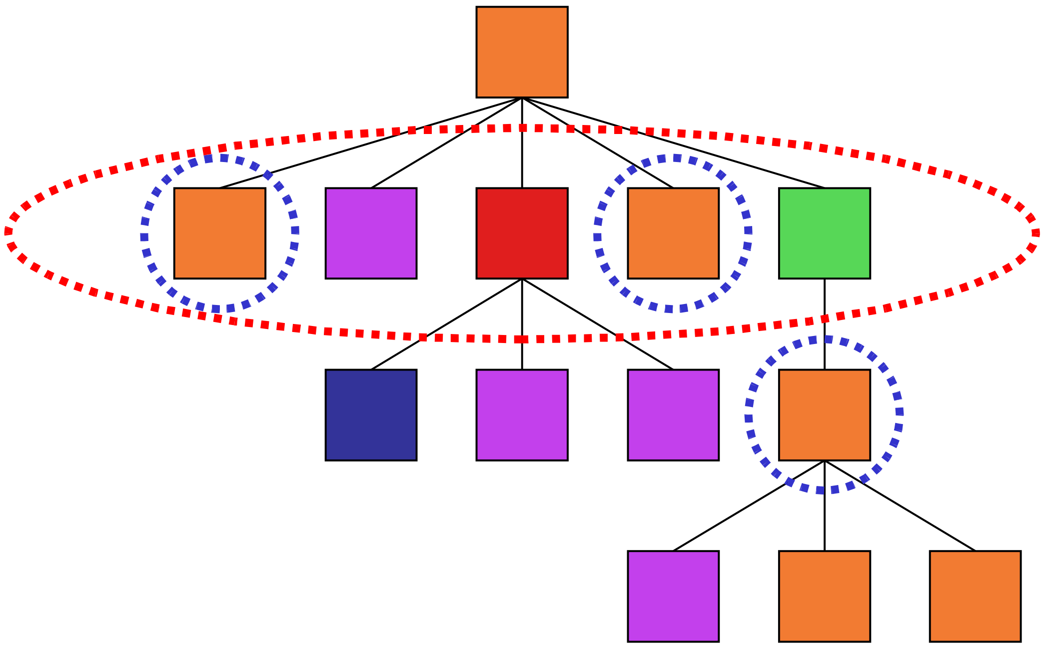
```
compos ::
(forall a. a -> m a) ->
(forall a b. m (a -> b) -> m a -> m b) ->
(forall a. t a -> m (t a)) ->
t c -> m (t c)
```

Scrap Your Boilerplate (SYB)

- Full generic traversals
- Based on similar idea of children
  - But is actual children, of different types!

```
gfoldl ::
(forall a b. Term a => w (a -> b)
                -> a -> w b)
-> (forall g. g -> w g)
-> a -> w a
```

SYB vs Play, children



SYB
Play

λ SYB continued

- Traversals are based on types:

```
0 `mkQ` f
f :: Expr -> Int
```

- mkQ converts a function on Expr, to a function on all types
- Then apply mkQ everywhere

Paradise benchmark

```
salaryBill :: Company -> Float
salaryBill = everything (+) (0 `mkQ` billS)

billS :: Salary -> Float
billS (S f) = f
```

SYB

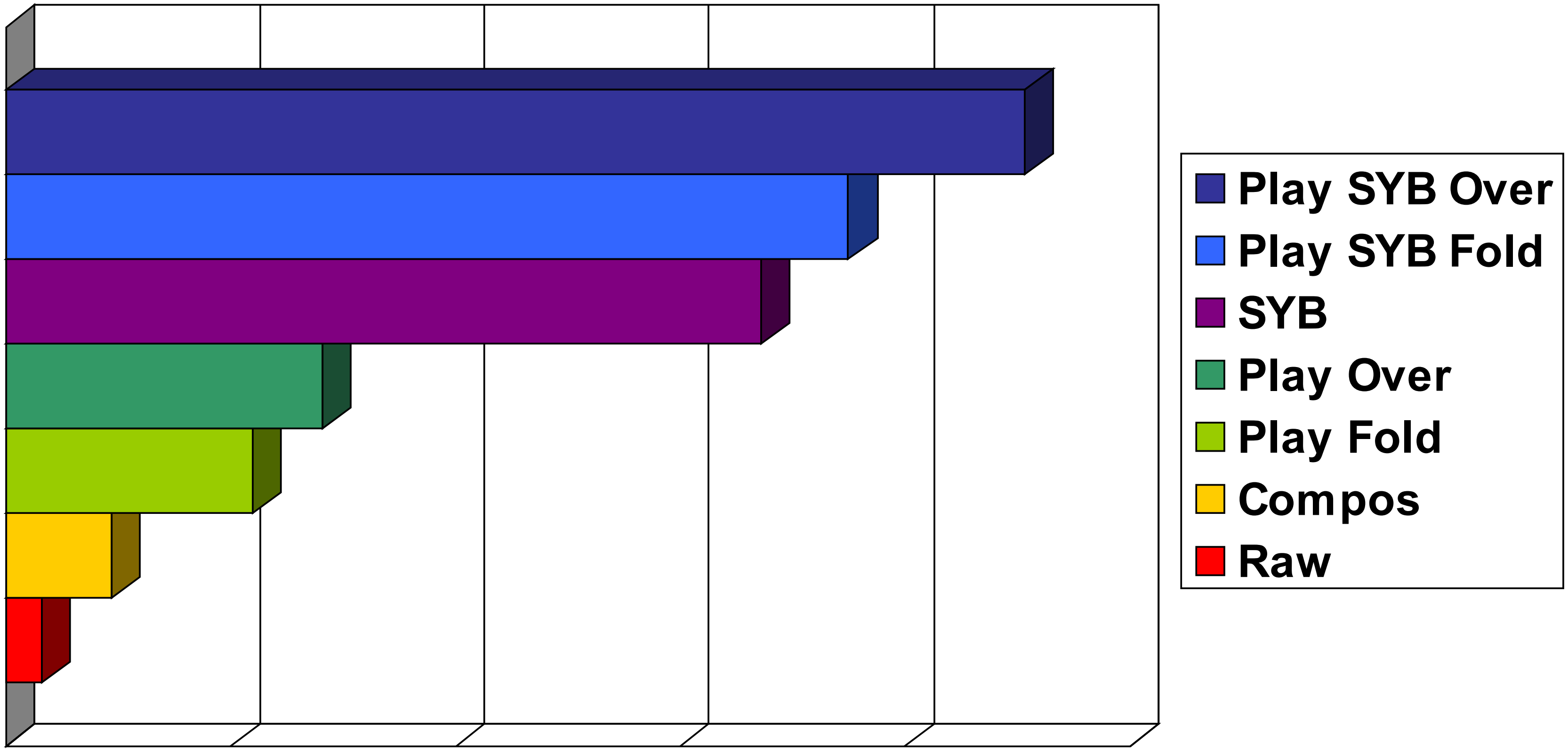
```
salaryBill c = case c of
    S s -> s
    _ -> composOpFold 0 (+) salaryBill c
```

Compos

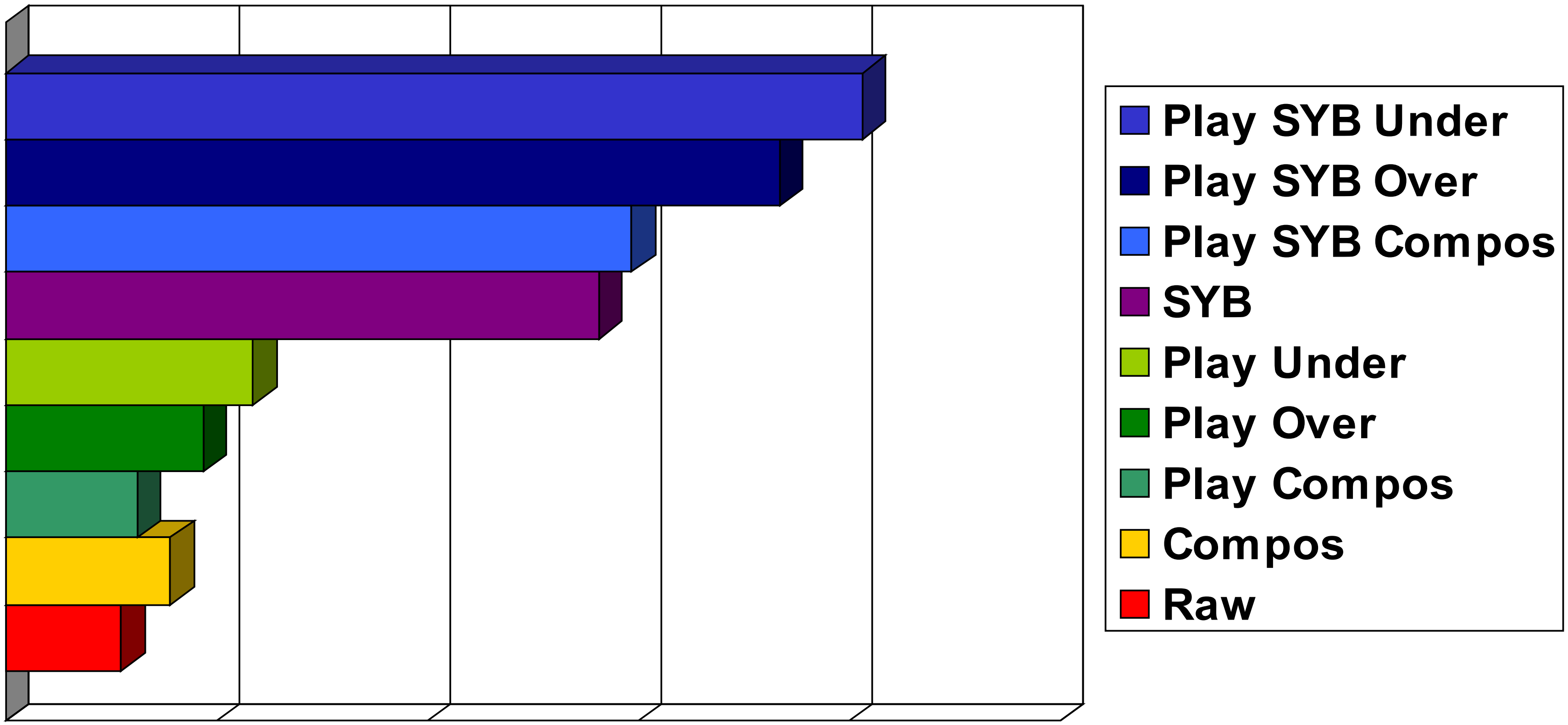
```
salaryBill x = sum [x | S x <- allOverEx x]
```

Play

λ Runtime cost - queries



Runtime cost - traversals



λ In the real world?

- Used in Catch about 100 times
- Used in Yhc.Core library
- Used by other people
  - Yhc Javascript converter
  - Settings file converter

λ Conclusions

- Generic operations with simple types
- Only 1 simple primitive

- If you only remember two operations:
  - allOver – queries
  - mapUnder – traversals