A Modern History of Lenses

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NICTA

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Goals

- the motivation for lenses
- the definition of and nomenclature for lenses
- the problems encountered for lenses
- the proposed solutions and recent developments
- the current solution
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We want to do programming and anything but functional programming is **completely insane**.
If you accept that fact of matter
then you also accept that data types must be *immutable*. 
Why Lenses?

OK let’s try that

data Street =
    Street {
        name :: String

    -- , ...

    }
Why Lenses?

data Employee =
    Employee {
        company :: Company
    , ...
    }  

data Company =
    Company {
        address :: Address
    , ...
    }  

data Address =
    Address {
        street :: Street
    , ...
    }
Then your team leader says to you

*Please set employer’s street address to upper-case.*
ARGH!

upperStreetFirst ::
   Employee
 -> Employee
upperStreetFirst e =
   e {
      company = (company e) {
         address = (address (company e)) {
            street = (street (address (company e))) {
               name = map toUpper
                  (name (street (address (company e))))
            }
         }
      }
   }
Scala insists on repeating history’s mistakes

def upperStreetFirst(e: Employee): Employee =
  e.copy(company = e.company.copy(
    address = e.company.address.copy(
      street = e.company.address.street.copy(
        name = e.company.address.street.name.
          map(_.toUpper)
      )
    )
  )
)
Why Lenses?

We must subsume dysfunctional programming because crushing victory is the best kind.

(company.address.street.name \%= toUpper) e

*We need lenses.*
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(company.address.street.name % toUpper) e

*We need lenses.*
What is a Lens?

Lens is a data structure

data Lens target field =
   Lens {
      get :: target -> field
   , set :: target -> field -> target
   }
What is a Lens?

With three laws

- \( \text{get lens } (\text{set lens } t f) \equiv f \)
- \( \text{set lens } (\text{get lens } t) t \equiv t \)
- \( \text{set lens } (\text{set lens } t f) f' \equiv \text{set lens } t f' \)
What is a Lens?
For example

Formerly

cOMPANY :: Employee -> Company
ADDRESS :: Company -> Address
STREET :: Address -> Street
NAME :: Street -> String
What is a Lens?
For example

**Becomes**

cOMPANY :: Employee ‘Lens‘ Company
ADDRESS :: Company ‘Lens‘ Address
STREET :: Address ‘Lens‘ Street
NAME :: Street ‘Lens‘ String
What is a Lens?
Lenses do lots of interesting things

Lenses can compose to a new Lens

(.) :: (a ‘Lens‘ b) -> (b ‘Lens‘ c) -> (a ‘Lens‘ c)

company :: Employee ‘Lens‘ Company
address :: Company ‘Lens‘ Address
company.address :: Employee ‘Lens‘ Address
What is a Lens?

Lens comes in a small variety of formulations

```haskell
data Lens target field =
    Lens {
        getset :: target -> (field -> target, field)
    }
```
What is a Lens?

Twan van Laarhoven lens

data Lens target field =
  Lens {
    run :: forall f. Functor f =>
      (field -> f field) -> (target -> f target)
  }

What is a Lens?

We can derive functions from Lens

-- modify the current field of a target
(\%=) :: Lens target field -> (f -> f) -> t -> t
Lens g s %= k =
      s <*> k . g
At this point, subsumption is achieved
We can do at least as well as dysfunctional programming

(company.address.street.name %~= toUpper) e

- We have won.
- We have won at winning.
Problem?

But subsuming archaic ideas is not a noble goal
Can we do better? What other problems exist? Can we win winning against winning?
Please set the object at "key" in the first array value to null.
Problem?

JSON

JArray [ JObject [ ("key", JNumber 7) ], JNumber 4 ]

JArray [ JObject [ ("key", JNumber 7) ], JNull ]
Problem?

But what if

- We don’t have an array?
- The array does not have a first value?
- The first value is not an object?
- The object does not have a "key"?

*We need partiality in our lenses.*
Problem?

But what if

- We don’t have an array?
- The array does not have a first value?
- The first value is not an object?
- The object does not have a "key"?

*We need partiality in our lenses.*
Partiality

Partial Lens

```haskell
data PartialLens target con =
  PartialLens (target -> Maybe (con -> target, con))
```
For example

```haskell
jArray ::
  PartialLens JSON [Json]
jArray =
  PartialLens (
  \j ->
    case j of
      JArray a ->
        Just (JArray, a)
      _ ->
        Nothing
  )
```
However

This structure violates many of our desirable lens properties that we had come to rely on. Our three laws do not translate.
The Polymorphic Update problem

Suppose we have this structure

data StringAnd a =
    StringAnd String a
And two values such as

aLens :: Lens (StringAnd a) a
aLens = ...

value :: StringAnd [Int]
value = StringAnd "abc" [1,5,10,100]
And we need to modify the [Int] field to a String. However,

\[(\%) \to \] 

\[
\text{Lens target field} \to \\
\text{field} \to \text{field} \to \\
\text{target} \to \text{target}
\]

\[(\%) \to \]

\[
\text{Lens (StringAnd a) a} \to \\
a \to a \to \\
(StringAnd a) \to StringAnd a
\]
The Polymorphic Update problem

We want to *polymorphically update* the field

(%=) aLensPoly ::
  (field -> newfield) ->
  (StringAnd field -> StringAnd newfield)
The Theory of Lenses

There have been many efforts to find a unifying theory of lenses to address the practical problems that we have identified.

An inexhaustive list follows.
Solutions

data-lens

- Started in 2008 by Edward Kmett; maintained by Russ O’Connor and me.
- Hit walls with doing polymorphic update and partiality when experimenting.
- Mostly abandoned now due to subsumption. The solution was ultimately found.
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fclabels

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- Originally only resolved the fundamental problems addressed by lenses.
- Now supports polymorphic update, but partiality is problematic.
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Asymmetric Lenses in Scala

- A paper in 2012 by me.
- An effort to invite discussion and improvements outside of Haskell.
- Discussion flourished, but Scala and "improvements" remain as elusive as yowies.
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Lenses in Scalaz

- `scalaz.{Lens, PLens, IndexedLens, IndexedPLens}`
- Polymorphic update, but still partiality eludes us, like yowies.
Solutions

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The Solution

Control.Lens

type Lens s t a b =
   Functor f =>
   (a -> f b) -> s -> f t

- Twan van Laarhoven lens representation
- Polymorphic update
- but... Partiality? Multiple update?
Control.Lens.Prism

```haskell
type Prism s t a b =
  (Applicative f, Choice p) =>
  p a (f b) -> p s (f t)
```

- Solves partiality.
- Importantly, is *principled*.
- Gives rise to diverse practical consequences.
- No more hacks or hitting walls!
Control.Lens.Traversal

```haskell
type Traversal s t a b =
  Applicative f =>
  (a -> f b) -> s -> f t
```

- View and update *multiple* values.
- Fold to *only view* multiple values.
and it gets interesting... 

- These structures are just functions.
- A Fold is a Traversal.
- A Prism is a Traversal.
- They are all a Lens.
- They all compose with (\cdot) (regular function composition).
and even more and more interesting…
But let’s leave it here :)