Optics, lenses and prisms

Motivation

OOP *universe* · *galaxy* (*milky*) · *sun* · *earth* · *mff* · *ms* · *rooms* ["S6"] · *molecules* [45] · *atom* [0] ⇝ "N"

Haskell (*head* · *atoms* · (!!23) · *molecules* · (!!"S6") · *rooms* · *ms* · *mff* · *earth* · *sun* · (!!*milky*) · *galaxies*) *universe* ⇝ "N"

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Haskell ☹

Problem

Substructure access in OOP does not really return data, but *references*.

Haskell doesn't have references (`IORef` doesn't count).

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Problem

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What now? Software engineering! Simulate the references!

What can we do with a reference?

- get
- set
- make a sub-reference

Which functional value can have all these properties at once?

Attempt 1:

```
data Ref big small = Ref
  { view :: big → small
  , over :: (small → small) → (big → big)
  }
```

Attempt 1

data Ref *big small* = Ref
  $\{ view :: big \to small, over :: (small \to small) \to (big \to big) \}$

data Two a = Two a a **deriving** Show

x = Ref $(\lambda(\text{Two } a \_) \to a)$ $(\lambda f\ (\text{Two } a\ b) \to \text{Two } (f\ a)\ b)$
y = Ref $(\lambda(\text{Two } \_\ b) \to b)$ $(\lambda f\ (\text{Two } a\ b) \to \text{Two } a\ (f\ b))$

t = Two 1 2

$view\ x\ t \quad \leadsto 1$
$over\ y\ (+1)\ t \quad \leadsto$ Two 1 3

$set\ x\ v = over\ x\ (const\ v)$
$set\ x\ 5\ t \quad \leadsto$ Two 5 2

Attempt 1

(Ref *v1 o1*) ‘*sub*‘ (Ref *v2 o2*) =
  Ref (*v2* ∘ *v1*) (*o1* ∘ *o2*)

t = Two (Two 1 2) (Two 3 4)

: *t x* ‘*sub*‘ *y* ⇝ Ref (Two (Two *b*)) *b*

view (*x* ‘*sub*‘ *y*) *t* ⇝ 2
over (*x* ‘*sub*‘ *y*) (∗10) *t* ⇝ Two (Two 1 20) (Two 3 4)

set r x = *over r* (*const x*)
set (*x* ‘*sub*‘ *y*) 1234 *t* ⇝ Two (Two 1 1234) (Two 3 4)

Improvements

- We want dot access with $x \cdot y \cdot x$!
- What if we want something better than OOP?
  - Safe reference to objects that may not exist?
    $left :: \mathrm{Ref}\ (\mathrm{Either}\ a\ b)\ a$?
  - Smart references to more objects (multi-edit)?
    Clamp in R: $x\ [x < 0] = 0; x\ [x > 1] = 1;$
  - Type-changing references?

Improvements

- We want dot access with $x \cdot y \cdot x$!
- What if we want something better than OOP?
  - Safe reference to objects that may not exist?
    left :: Ref (Either *a b*) *a*?
  - Smart references to more objects (multi-edit)?
    Clamp in R: $x\ [x < 0] = 0; x\ [x > 1] = 1;$
  - Type-changing references?

Let's start with the hardest part.

NB.: Because Ref *big small* represents a 'zoom' on a small object, it's usually called a Lens.

Optics, attempt 2

We have:

$$(\cdot) :: (b \to c) \to (a \to b) \to (a \to c)$$

We want:

$$(\cdot) :: \mathsf{Lens}\ x\ y \to \mathsf{Lens}\ y\ z \to \mathsf{Lens}\ x\ z$$

Lenses thus must be functions!

$$\textbf{type}\ \mathsf{Lens}\ a\ b = \_ \to \_$$

At the same time we know:

$$set' :: (\_ \to \_) \to (b \to b) \to (a \to a)$$
$$get' :: (\_ \to \_) \to (b \to b) \to (a \to b)$$

Which type $(\_ \to \_)$ can easily produce both $(a \to a)$ and $(a \to b)$?

Optics, attempt 2

$$(\bullet) :: (b \to c) \to (a \to b) \to (a \to c)$$
$$(\bullet) :: \text{Lens } x\ y \to \text{Lens } y\ z \to \text{Lens } x\ z$$

Parameter order must be ok:

$$\text{Lens } \mathit{big}\ \mathit{small} = \text{Something } \mathit{small} \to \text{Something } \mathit{big}$$

i.e., the lens convers ‘something that works with a part’ to ‘something that works with a whole’

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We need to use this Something in:

$\mathit{set'} :: (\text{Something}\ \mathit{small} \to \text{Something}\ \mathit{big}) \to (\mathit{small} \to \mathit{small}) \to (\mathit{big} \to \mathit{big})$
$\mathit{get'} :: (\text{Something}\ \mathit{small} \to \text{Something}\ \mathit{big}) \to (\mathit{small} \to \mathit{small}) \to (\mathit{big} \to \mathit{small})$

Optics, attempt 2

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Something *big* must be convertible to both *small* and *big*!

Optics, attempt 2

Let's add a small decoration

$$set' :: ((small \to \text{Set } small) \to (big \to \text{Set } big)) \to (small \to \text{Set } small) \to (big \to \text{Set } big)$$
$$get' :: ((small \to \text{Get } small) \to (big \to \text{Get } big)) \to (small \to \text{Get } small) \to (big \to \text{Get } big)$$

The user may create lenses that work with a decoration, and eventually remove it.

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The user may create lenses that work with a decoration, and eventually remove it.

After the removal, we need this to hold:

$$\begin{aligned} \text{Set } small &\rightsquigarrow small \\ \text{Set } big &\rightsquigarrow big \\ \text{Get } small &\rightsquigarrow small \\ \text{Get } big &\rightsquigarrow small \end{aligned}$$

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\text{Get } small &\rightsquigarrow small \\
\text{Get } big &\rightsquigarrow small
\end{aligned}$$

$$\begin{aligned}
id\ S &\rightsquigarrow S \\
id\ B &\rightsquigarrow B \\
const\ S\ S &\rightsquigarrow S \\
const\ S\ B &\rightsquigarrow S
\end{aligned}$$


Vorsicht
Funktor
2 m Abstand halten

Optics, attempt 2

$$
\begin{aligned}
&\mathit{runIdentity} :: \text{Identity } \mathit{small} \to \mathit{small} \\
&\mathit{runIdentity} :: \text{Identity } \mathit{big} \to \mathit{big} \\
&\mathit{getConst} :: (\text{Const } \mathit{small})\ \mathit{small} \to \mathit{small} \\
&\mathit{getConst} :: (\text{Const } \mathit{small})\ \mathit{big} \to \mathit{small}
\end{aligned}
$$

We get

```
set' :: ((small → Identity small) → (big → Identity big)) → (small → Identity small) → (big → Identity big)
set' = id
get' :: ((small → Const small small) → (big → Const small big)) → (small → Const small small) → (big → Const small big)
get' = id
```

$$
\begin{aligned}
&\mathit{over}\ \mathit{lens}\ f = \mathit{runIdentity} \cdot \mathit{lens}\ (\text{Identity} \cdot f) \\
&\mathit{view}\ \mathit{lens}\ f = \mathit{getConst} \cdot \mathit{lens}\ (\text{Const} \cdot f)
\end{aligned}
$$

What got better?

Naive reference:

$$\textbf{data}\ \mathrm{Ref}\ b\ s = \{ view :: b \to s,\ over :: (s \to s) \to (b \to b) \}$$

Problems:

- What if someone invents 3rd operation?
- No possibility to refer to more items
- The operation of 'picking the item' is implemented twice

Functorial reference:

$$\mathrm{Lens}\ b\ s :: \forall f.\mathrm{Functor}\ f \Rightarrow (s \to f\ s) \to b \to f\ b$$

- Implements a single operation $b \to (s, s \to b)$
- Pipeline: $b \rightsquigarrow s \rightsquigarrow f\ s \rightsquigarrow f\ b$
- Operations can be implemented by throwing in a functor
  $\mathrm{Identity}\ b \equiv b, (\mathrm{Const}\ s)\ b \equiv s, \ldots$

Lenses — implementation

Actual implementation of functorial lenses:

$$\text{Lens } big\ small :: \forall f.\text{Functor } f \Rightarrow (small \to f\ small) \to big \to f\ big$$

- gets a function that is able to wrap a small 'part' into a 'whole'
- should produce a function that is able to rewrap the 'whole'
- the implementation is strictly type-directed:
  1. we get the whole (as the 2nd parameter, of type *big*)
  2. we cut out a piece of type *small*
  3. we can have *small* wrapped into *f small* (using 1st parameter)
  4. from *f small* we want to make *f big*, but we only know *small* → *big*
  5. because *f* is a functor, we can do this with *fmap*

Lens can be trivially made from a getter and a setter.

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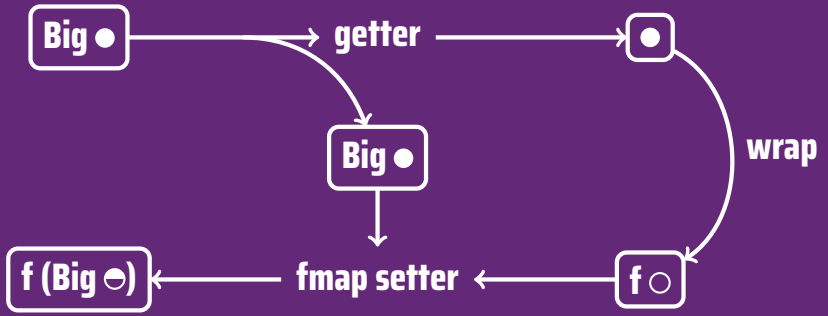
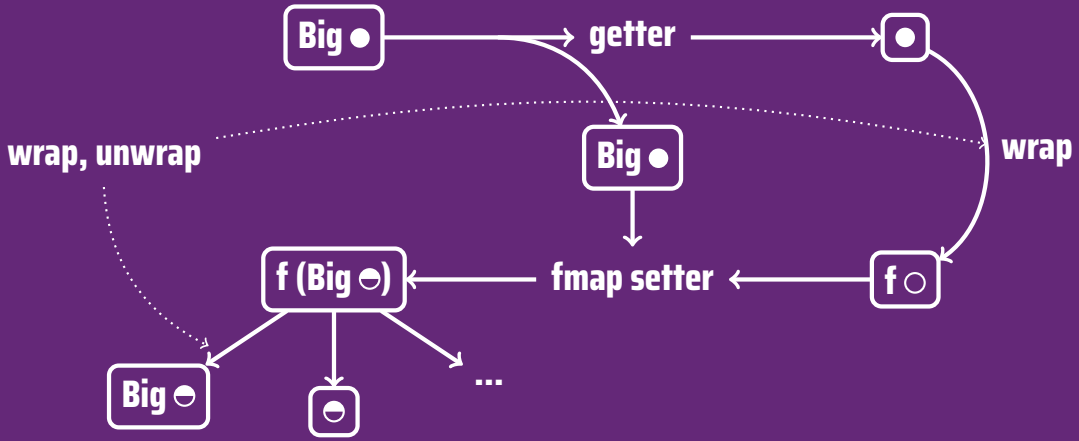
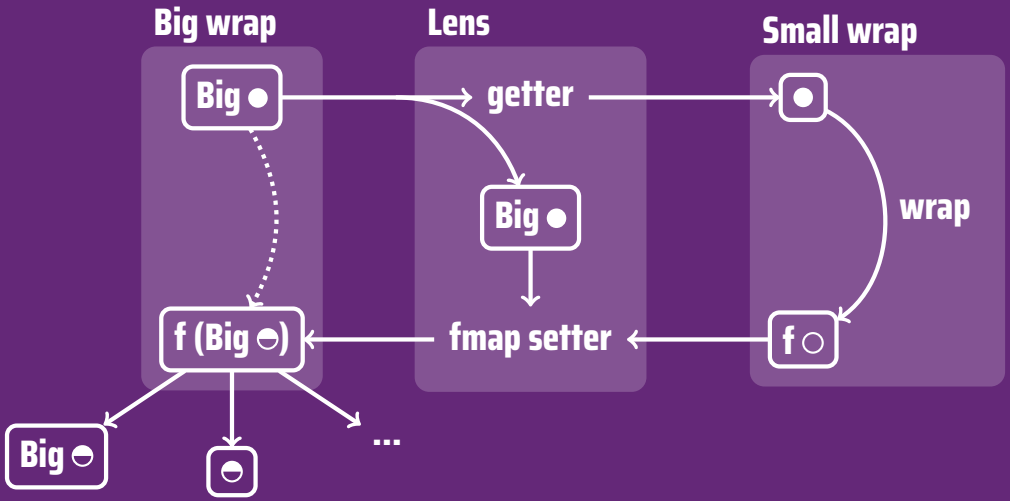

Big ●
getter
●
wrap
Big ●
f (Big ◓)
fmap setter
f ○


Big ●
getter
●
wrap, unwrap
Big ●
wrap
f (Big ◓)
fmap setter
f ○
Big ◓
◓
...


Big wrap
Lens
Small wrap
Big
getter
Big
wrap
f (Big)
fmap setter
f
Big
...

Lenses – result

Overall lens type (needs `-XRankNTypes`):

$$\textbf{type}\ \text{Lens}\ a\ b = \forall f.\text{Functor}\ f \Rightarrow (b \to f\ b) \to (a \to f\ a)$$

What does it look like?

$$x :: \text{Lens}\ (\text{Two}\ a)\ a$$
$$x :: \text{Functor}\ f \Rightarrow (a \to f\ a) \to (\text{Two}\ a \to f\ (\text{Two}\ a))$$
$$x\ wrap\ (\text{Two}\ a\ b) = fmap\ (\lambda a' \to \text{Two}\ a'\ b)\ \$\ wrap\ a$$
$$y\ wrap\ (\text{Two}\ a\ b) = fmap\ (\lambda b' \to \text{Two}\ a\ b')\ \$\ wrap\ b$$

Generically from a getter and setter:

$$lens :: (a \to b) \to (a \to b \to a) \to \text{Lens}\ a\ b$$
$$lens\ getter\ setter\ wrap\ a = fmap\ (setter\ a)\ \$\ wrap\ (getter\ a)$$

Lenses vs. dots

Type tetris success:

$$
\begin{aligned}
&(\bullet) :: \mathsf{Functor}\ f \\
&\quad \Rightarrow ((b \to f\ b) \to (a \to f\ a)) \\
&\quad \to ((c \to f\ c) \to (b \to f\ b)) \\
&\quad \to ((c \to f\ c) \to (a \to f\ a))
\end{aligned}
$$

$$
(\bullet) :: \mathsf{Lens}\ a\ b \to \mathsf{Lens}\ b\ c \to \mathsf{Lens}\ a\ c
$$

(a, b are flipped in `Lens` definition!)

Lenses — implementation

$$set :: \text{Lens } a\ b \to b \to a \to a$$
$$set\ l\ v = runIdentity \cdot l\ (\text{Identity} \cdot const\ v)$$

$$over :: \text{Lens } a\ b \to (b \to b) \to a \to a$$
$$over\ l\ f = runIdentity \cdot l\ (\text{Identity} \cdot f)$$

$$view :: \text{Lens } a\ b \to a \to b$$
$$view\ l = getConst \cdot l\ \text{Const}$$

Lenses — usage

$$\mathit{set}\ x :: b \to \mathsf{Two}\ b \to \mathsf{Two}\ b$$
$$\mathit{over}\ (x \bullet y)\ (+1) :: \mathsf{Num}\ b \Rightarrow \mathsf{Two}\ (\mathsf{Two}\ b) \to \mathsf{Two}\ (\mathsf{Two}\ b)$$
$$\mathit{view}\ (x \bullet y \bullet x) :: \mathsf{Two}\ (\mathsf{Two}\ (\mathsf{Two}\ b)) \to b$$

A nice bonus: Lenses compose in the more “humane” order:

$$\begin{aligned} &\mathit{set}\ (x \bullet y)\ 10\ (\mathsf{Two}\ (\mathsf{Two}\ 1\ 2)\ (\mathsf{Two}\ 3\ 4)) \\ &\quad \rightsquigarrow \quad \mathsf{Two}\ (\mathsf{Two}\ 1\ 10)\ (\mathsf{Two}\ 3\ 4) \end{aligned}$$

Lenses — usage

$$set\ x :: b \to \text{Two}\ b \to \text{Two}\ b$$
$$over\ (x \cdot y)\ (+1) :: \text{Num}\ b \Rightarrow \text{Two}\ (\text{Two}\ b) \to \text{Two}\ (\text{Two}\ b)$$
$$view\ (x \cdot y \cdot x) :: \text{Two}\ (\text{Two}\ (\text{Two}\ b)) \to b$$

A nice bonus: Lenses compose in the more “humane” order:

$$set\ (x \cdot y)\ 10\ (\text{Two}\ (\text{Two}\ 1\ 2)\ (\text{Two}\ 3\ 4))$$
$$\rightsquigarrow \quad \text{Two}\ (\text{Two}\ 1\ 10)\ (\text{Two}\ 3\ 4)$$

Author: Twan van Laarhoven (2009)

✎ https://www.twanvl.nl/blog/haskell/cps-functional-references

Edward Kmett (`import Control.Lens`)

"newtype PlanT *k i o m a* = PlanT {*runPlanT* :: $\forall r.(a \to m\ r) \to (o \to m\ r \to m\ r) \to$

$(\forall z.(z \to m\ r) \to k\ i\ z \to m\ r \to m\ r) \to m\ r \to m\ r$} is a monad I actually use."

More optics!

- *allItems* :: Lens [*a*] _
- *left* :: Lens (Either *a b*) _

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These concepts are called Traversal and Prism.

NB.: the types of stuff are going to get a bit out of hand now. Intuition from the Functorial lenses still holds.

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- *allItems* :: Lens [*a*] _
- *left* :: Lens (Either *a b*) _

These concepts are called Traversal and Prism.

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Traversal

If we want to apply optics to multiple 'small' parts, we need to be able to reconnect the wrappers later. Applicative is the usual solution:

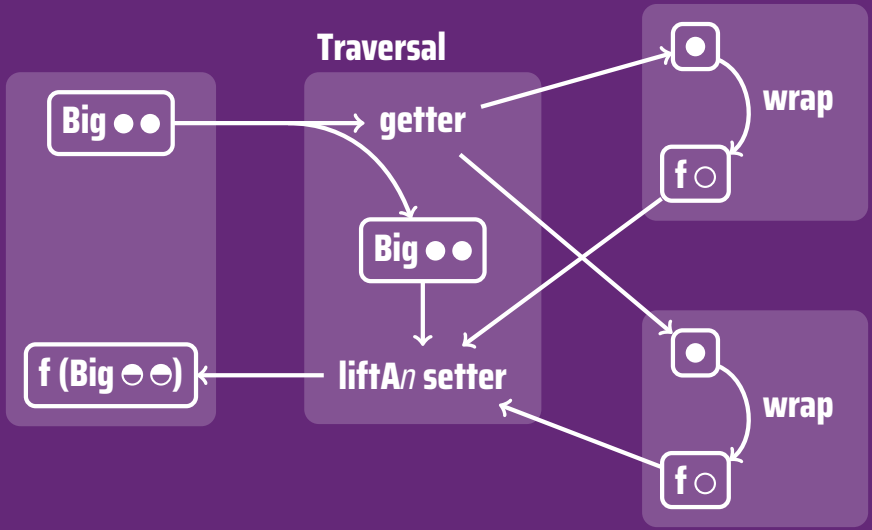
```
data Two a = Two a a deriving Show

both wrap (Two a b) = Two <$> wrap a <*> wrap b
```

Demo:

```
a = Two (Two 1 2) (Two 3 4)

set both 5 a              ⇝ Two 5 5
set (both • x) 5 a        ⇝ Two (Two 5 2) (Two 5 4)
set (x • both) 5 a        ⇝ Two (Two 5 5) (Two 3 4)
over (both • y) (+10) a   ⇝ Two (Two 1 12) (Two 3 14)
```


Traversal
Big ●●
getter
wrap
f ○
Big ●●
f (Big ◓◓)
liftA*n* setter
wrap
f ○

```
:t view both
```

```
:t view both
```

view both :: **Monoid *c* ⇒ Two *c* → *c***

...but where did the Monoid come from?!

view both :: Monoid $c \Rightarrow$ Two $c \to c$

Recall the effect-gluing instance for Const:

instance Monoid $b \Rightarrow$ Applicative (Const b)

Use:

view both (Two (Sum 1) (Sum 2))
$\rightsquigarrow$ Sum {*getSum* = 3}

view both (Two [1, 2] [3, 4])
$\rightsquigarrow$ [1, 2, 3, 4]

Traversing

Conveniently, *traverse* is a traversal for everything Traversable:

$$traverse :: (\text{Applicative } f, \text{Traversable } t) \Rightarrow (a \to f\ b) \to (t\ a \to f\ (t\ b))$$

(The type is just a little more decorated Lens $a\ b$)

$$over\ (traverse \cdot y)\ (+1)\ [\text{Two } 1\ 2, \text{Two } 3\ 4] \rightsquigarrow [\text{Two } 1\ 3, \text{Two } 3\ 5]$$

$$listOf\ l = getConst \cdot l\ (\lambda x \to \text{Const}\ [x])$$

$$listOf\ both\ \$\ \text{Two}\ (\text{Two } 1\ 2)\ (\text{Two } 3\ 4) \rightsquigarrow [\text{Two } 1\ 2, \text{Two } 3\ 4]$$

$$listOf\ (both \cdot y)\ \$\ \text{Two}\ (\text{Two } 1\ 2)\ (\text{Two } 3\ 4) \rightsquigarrow [2, 4]$$

$$listOf\ (y \cdot both)\ \$\ \text{Two}\ (\text{Two } 1\ 2)\ (\text{Two } 3\ 4) \rightsquigarrow [3, 4]$$

Traversing

SQL exercise:

ident *wr s = wr* *s* – don't do anything lens (same as id)

ignored wr s = pure s – discard changes

filtered cond f s = **if** *cond s* **then** *f s* **else** *pure s*

over (*both* ∘ *both* ∘ *filtered even*) (*'div'*2) $ Two (Two 1 2) (Two 3 4)

⇝ Two (Two 1 1) (Two 3 2)

Iso

Iso is a representation-changing lens (the name comes from isomorphisms).

```
asString :: (Show a, Read a) ⇒ Lens a String
asString ff a = fmap read $ ff (show a)

set (both • asString • traverse • filtered (≡ '3')) '5' $ Two 103 430
    ⇝ Two 105 450
```

(NB: without the explicit type, *asString* doesn't know to return the same *a*)

Prism

Prism is a special case of Traversal, that is guaranteed to match at most one target.

- *view* doesn't require monoids, instead we have *preview* with Maybe (implemented via First functor)
- it can be reversed (*review*, *re*)

Practical alternative definition: Iso that is total in only one direction.

Prism

preview *_Right* (Right 5) ⇝ Just 5
preview *_Right* (Left 5) ⇝ Nothing

view (*re* *_Right*) 3 ⇝ Right 3
review *_Right* 3 ⇝ Right 3

preview (*prefixed* `"tele"`) `"telescope"` ⇝ Just `"scope"`
preview (*prefixed* `"tele"`) `"orange"` ⇝ Nothing
review (*prefixed* `"tele"`) `"graph"` ⇝ `"telegraph"`
over (*prefixed* `"tele"`) *reverse* `"telegraph"` ⇝ `"telehparg"`
over (*prefixed* `"tele"`) *reverse* `"carrot"` ⇝ `"carrot"`

Intuition: Prisms generalize the pairing of data constructors and their pattern matches.

Lens library

`Control.Lens` implements the Van Laarhoven lenses with many interesting side benefits.

Bonusy:

- TemplateHaskell
- useful operators

Other libraries:

- `Lens.Micro` (less funcionality with negligible bloat)
- `Optics.Optic` (easier encoding, less scary types, doesn't support dot access)
- `Prolens` (encoding in profunctors gives much scarier types and lots of speed, absolutely no bloat and minimal side functionality)

@IMPUREPICS

HOW MANY LEVELS OF LENSES ARE YOU ON?

```
obj.getter()
obj.setters()
```

```
get: s -> a
set: a -> s -> s
```

```
type Lens s a =
∀f. Functor f
=> (a -> f a)
-> (s -> f s)
```

```
type Lens s t a b =
∀p. Strong p
=> p a b
-> p s t
```

You can use TemplateHaskell to automatically make optics for your ADTs:

```
{-# LANGUAGE TemplateHaskell #-}

import Control.Lens

data Two a = Two {_x :: a, _y :: a} deriving Show
makeLenses ''Two

x :: Functor f ⇒ (a → f a) → Two a → f (Two a)
y :: Functor f ⇒ (a → f a) → Two a → f (Two a)
```

(the underscores are a convention)

Name collisions are solved via typeclasses:

```
{-# LANGUAGE TemplateHaskell #-}
{-# LANGUAGE FlexibleInstances #-}
{-# LANGUAGE FunctionalDependencies #-}

import Control.Lens

data Two a = Two {_twoX :: a, _twoY :: a}
makeFields ''Two

data Three a = Three {_threeX :: a, _threeY :: a, _threeZ :: a}
makeFields ''Three

x :: (Functor f, HasX s a) => (a -> f a) -> s -> f s
```

(the prefixing with underscored constructor name is a convention)

What follows is a random review of useful lensy constructions.

Operators!

prefix	infix	State
view	`^.`	
set	`.~`	`.=`
over	`%~`	`%=`
toListOf	`^..`	
preview	`^?`	
	`+~, -~, *~`	`+=, -=, *=`

Tool: `&` is a flipped `$`.

Operators and State utils

```
(0, 1, 0, 1, 0, 1) & _1 .~ 7
                   & _2 %~ (5*)
                   & _3 .~ (-1)
                   & _4 .~ "orange"
                   & _5 +~ 2
                   & _6 *~ 3
  ⇝ (7, 5, -1, "orange", 2, 3)
```

```
runPhysics :: State SomeWorld ()
runPhysics dT =
  zoom (gameObjects . actors) $
    do Vec x y ← use (player . speed)
       player . position . x += dT * x
       player . position . y += dT * y
```


MY INNOCENT
CODEBASE
@impurepics

import Data.Aeson.Lens

Using prisms instead of (ugly!) pattern matches:

```
"[1, \"x\"]" ^? nth 0 . _Number
  ⇝ Just 1.0
```

```
"[1, \"x\"]" ^? nth 1 . _Number
  ⇝ Nothing
```

```
"[10.5]" ^? nth 0 . _Integer
  ⇝ Just 10
```

```
"[{\"x\":1, \"y\":2}, {\"x\":3, \"y\":[]}]"
  ^.. values . members . _Integer
  ⇝ [1,2,3]
```

```
"[{\"x\":1, \"y\":2}, {\"x\":3, \"y\":4}]"
  ^.. values . key "x" . _Double
  ⇝ [1.0,3.0]
```

Indexes, filters, ...

```
import Control.Lens.Indexed
import Control.Lens.Combinators
```

Indexed lenses contain a 'hidden' index that can be extracted and accessed later

```
['a'..'z'] ^.. itraversed . filtered (∈ "hello")
    ⇝ "ehlo"
['a'..'z'] ^.. itraversed . filtered (∈ "hello") . withIndex
    ⇝ [(4,'e'),(7,'h'),(11,'l'),(14,'o')]
['a'..'z'] ^.. itraversed . indices odd
    ⇝ "bdfhjlnprtvxz"
```

Cool utilities:

```
has (element 10) [1,2,3]    ⇝ False
is _Left (Right 5)          ⇝ False
hasn't _Left (Right 5)      ⇝ True
```

```
"Some random words" & worded
  %~ show . length
    ⇝ "4 6 5"
"AAAAARGGGHH!" & _tail . mapped
  %~ toLower
    ⇝ "Aaaaargggghh!"
```

IO!

What else can the GHC runtime do for you?

- UNIX-like files & networking
- concurrent computation and synchronization
- parallel computation
- references and actual pointers
- FFI

Communication of the user with the program

- environment variables ('env')

```
import System.Environment

getEnv :: String → IO String
lookupEnv "PATH" :: IO (Maybe String)
getEnvironment :: IO [(String, String)]
```

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```

- commandline parameters

```
getArgs :: IO [String]
getProgName :: IO String
getExecutablePath :: IO FilePath
```

Communication of the user with the program

- exit-code

```
import System.Exit

die "okay sorry" :: IO a

exitWith ExitSuccess :: IO a
exitWith (ExitFailure 3) :: IO a
```

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die "okay sorry" :: IO a

exitWith ExitSuccess :: IO a
exitWith (ExitFailure 3) :: IO a
```

- reading and writing from/to file descriptors

```
import System.IO

openFile "test" WriteMode :: IO Handle
hClose h :: IO ()

hGetChar h :: IO Char
hPutChar h 'c' :: IO ()
```

Communication of the user with the program

- sending and catching of signals

```
import System.Posix.Signals

raiseSignal sigSTOP :: IO ()
signalProcess sigKILL 1 :: IO ()
```

Communication of the user with the program

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```
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data Handler = Default | Ignore
    | Catch (IO ()) | CatchOnce (IO ()) | ...
installHandler sigTERM
   (Catch $ putStrLn "nope")
   Nothing
    :: IO Handler
```

(package `unix` contains most of the other low-level primitives)

How do you recognize a high-quality UNIX program?

How do you recognize a high-quality UNIX program?

It prints out an useful `--help`.

optparse-applicative

Abstraction: We will remember the optional commandline argument properties as monoids. The parameter parsers can be applicatively connected to a commandline parser that directly fills in a given data structure.

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```
import Options.Applicative
import Data.Semigroup ((◇))

theOption :: Parser Bool
theOption = switch $ long "good"
                   ◇ short 'g'
                   ◇ help "Should it be really good?"

optInfo = info (helper ⟨∗⟩ theOption)
  $ progDesc "good shows current level of goodness"
  ◇ header "A program that shows if it's good."
  ◇ footer "See more information on www.good.program.hu"
```

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```

optparse-applicative

```
main = do opt ← execParser $ optInfo
          putStrLn $ if opt
                     then "yeah it's good"
                     else "not good at all!"
```

```
$ ./good
not good at all!
$ ./good -x
Invalid option `-x'

Usage: ./good [-g|--good]
$ ./good -g
yeah it's good
```

optparse-applicative

```
main = do opt ← execParser $ optInfo
          putStrLn $ if opt
                     then "yeah it's good"
                     else "not good at all!"
```

```
$ ./good
not good at all!
$ ./good -x
Invalid option `-x'

Usage: ./good [-g|--good]
$ ./good -g
yeah it's good
```

```
$ ./good -h
A program that shows if it's good.

Usage: good [-g|--good]
  good shows current level of goodness

Available options:
  -h,--help                Show this help text
  -g,--good                Should it be really good?

See more information on www.good.program.hu
```

- Strings

```
optOutput = strOption
  $ long "output"
  ◇ short 'o'
  ◇ metavar "FILE"
  ◇ value "out.txt"
  ◇ showDefault
  ◇ help "Write output to FILE"
```

- Integers

```
optLevel = option
  $ long "level"
  ◇ short 'l'
  ◇ help "Level of whatever"
```

- combination (product)

```
data CmdLineOpts = CmdLineOpts {level :: Int,
                                output :: String}

allOptions = CmdLineOpts <$> optLevel <*> optOutput
```

- combination of alternatives

```
data OptionalOutput = FileOutput String | StdOutput

optionOptionalOutput = FileOutput <$> optOutput
  <|> flag' StdOutput (long "stdout"
                       <> help "write to stdout")
```