@AndrzejWasowski
Andrzej Wąsowski
Florian Biermann

Advanced Programming

Lenses: Functional updates to complex values

IT UNIVERSITY OF COPENHAGEN

SOFTWARE QUALITY RESEARCH

Lenses

Summary

- It is **easy to navigate** purely to values (get)
- It is **difficult to create deep nested assignments**
- The **more complex** the structure, **harder to modify** it purely
  - Very hard for XML, JSon, and YAML schema
  - Foster et al. use XML as an example
  - The principle extends to any trees (e.g. abstract syntax trees of program code)

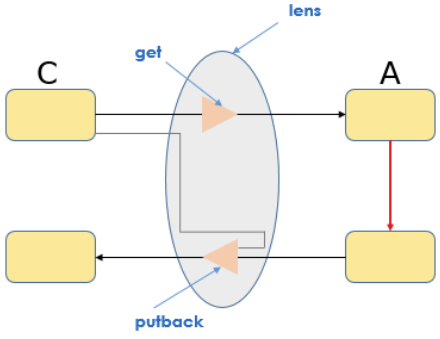
Lenses are a uniform architecture and an algebra of combinators to systematically and simultanously create set and get functions for complex structures.

- Specify the **get** and **set** (**put**, **replace**) functions (expected)
- Lenses provide a way to **compose nested setters and getters**
- Guarantee that **algebraic laws capturing well behavedness** hold
- For a new lense you build, **test laws with PBT**

Lens

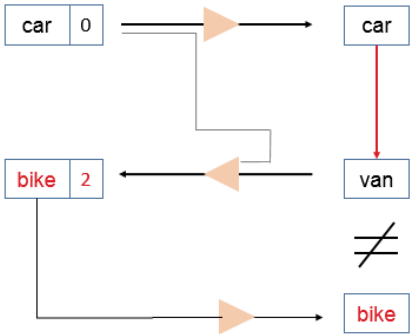
Definition

Def. A lense l from concrete (larger) representation (type) C to an abstract (smaller) representation (type) A comprises a partial function $l \nearrow\colon C \to A$ (`get`) and a function $l \searrow\colon A \to C \to C$ (AKA `putback` / `put` / `set` / `replace`)



- In Monocle (the library we use), lenses are (roughly) called optics
- We mostly look at three types of optics:
  - `Lens[C,A]` (total lens)
  - `Optional[C,A]` (a partial lense),
  - `Traversal[C,A]` (lens for elements in a collection)

Put-Get Law



- Consider a lens that operates on vehicle-number records
- It extracts a view on the vehicle type (a usual getter/setter for a field)
- We extract value `car` and want to put back `van`
- When we get the value of vehicle type again we would like to get a `van`, not something else!

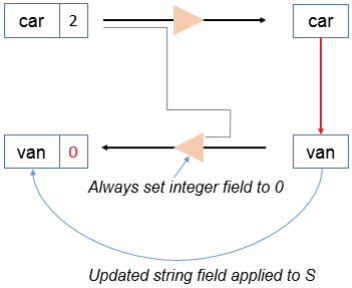
Put-Get Law

For a lense l, each concrete value c and each abstract view a we got: $l \nearrow (l \searrow (a)(c)) = a$

In Scala/Monocle: `l.get(l.replace(a)(c)) == a`

Foster et al. formulate the law using an equality that makes sense for partial lenses. too.

Get-Put Law



- Consider a lens that operates on vehicle-number records (as before)
- It extracts a view on the vehicle type (as before)
- On `put` it always sets the number to zero, regardless of what was there before
- This is a confusing side-effect for a setter!

Get-Put Law

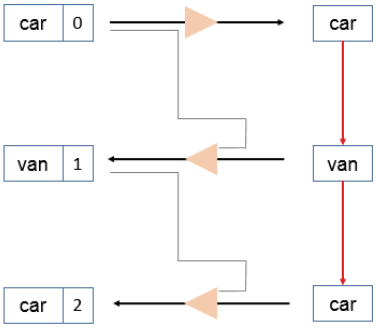
For a lense l and each concrete value c we have: $l \searrow (l \nearrow (c))(c) = c$

In Scala/Monocle: `l.replace(l.get(c))(c) == c`

Again, for partial lenses we only eforce the law if set/get do not fail.

Def. A lens satisfying Put-Get and Get-Put is called **well-behaved**.

Put-Put Law



- Consider a lens that operates on vehicle-number records (as before)
- It extracts a view on the vehicle type (as before)
- This lens, has another problem, even though we put `car` second time, we obtain a different record than before.
- The putting of `van` is not completely anihilated!

Get-Put Law

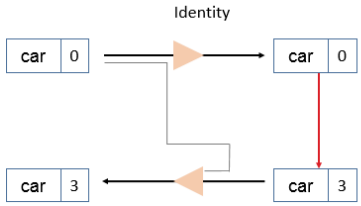
For a lens l, and all values c, a, and a' we have: $l \searrow (a')(l \searrow (a)(c)) == l \searrow (a', c)$

In Scala syntax: `l.replace(a1)(l.replace(a)(c)) == l.replace(a1)(c)`

Def. A lens satisfying Put-Get, Get-Put, and Put-Put is called **very well-behaved**.

Identity

An example Lens



- A lens that gets the entire object
- And updates the entire object
- **Question:** what is `identityLens[Int].get(42)`?
- **Question:** what is `identityLens[Int].replace(42)(13)`?

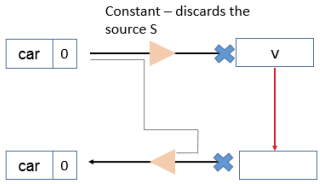
In Scala syntax:

```
def identityLens[A] = Lens[A,A](c =>c)(a =>c =>a)
```

Total, very well-behaved.

Constant

An example Lens



- A lens that always reads the same value
- And does not modify the concrete objects
- **Question:** what is `constLens(13).get(42)`?
- **Question:** what is `constLens(13).replace(7)(42)`?

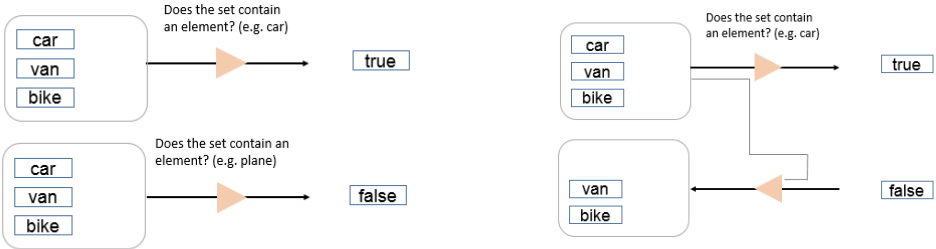
In Scala syntax:

```
def constLens[C,A](default: A) = Lens[C, A](c =>default)(_ =>c =>c)
```

Total, not well-behaved.

Set Membership (Contains)

An example Lens



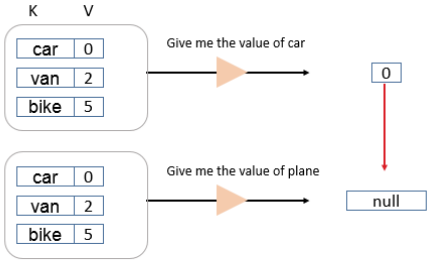
In Scala syntax:

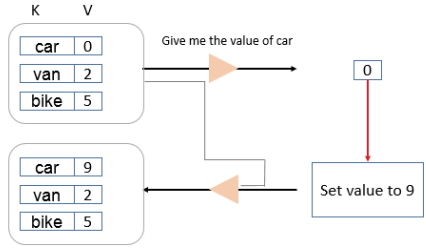
```
def contains[T](x: T) =
  Lens[Set[T],Boolean]
    (get =_.contains (x))
    (set =b =>c =>if b then c.incl(x) else c.excl(x))
```

Total, very well-behaved.

Index (in a map)

An example Lens



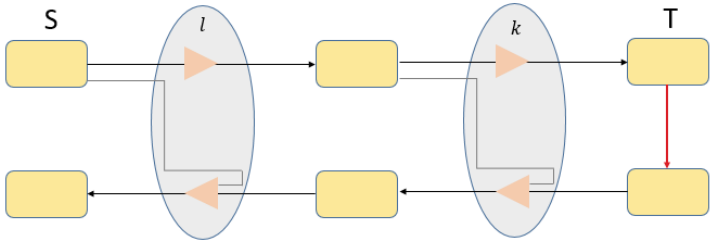


In Scala syntax:

```
1 def index[K, V](k: K): Optional[Map[K,V],V] =
2   def get(m: Map[K, V]): Option[V] = m.get(k)
3   def replace(v: V)(m: Map[K, V]): Map[K,V] = m + (k->v)
4   Optional[Map[K, V], V](get)(replace)
```

Partial, very well-behaved.

Composing Lenses




```
1  def compose[S, A, T](l: Lens[S, A])(k: Lens[A, T]): Lens[S, T] =
2    def get(s: S): T = k.get(l.get(s))
3    def replace(t: T)(s: S): S =
4      l.replace(k.replace(t)(l.get(s)))(s)
5    Lens[S, T](get)(replace)
```

A composition of total lenses is total, a composition of well-behaved lenses is well-behaved

Lenses

Concluding Remarks

- There are many lens libraries for Scala (and other functional languages)
- AFAIK, the first implementation was in Haskell
- Monocle uses slightly different identifiers and types
- It also uses type classes, macros, and annotations to derive some lenses automatically
- All this we know so that you are now well equipped to read `https://www.optics.dev/Monocle/docs/optics/lens`

Credits: I used figures from presentations of Nate Foster in this lecture