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Advanced Programming

Lenses: Functional updates to complex values

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SOFTWARE QUALITY RESEARCH

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Lenses

Summary

- Typically **easy to navigate** purely to values (get) but 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)

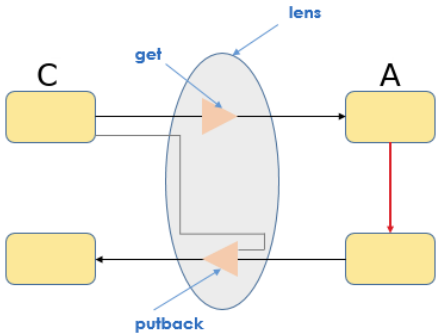
Lenses are a uniform architecture and an algebra of combinators to systematically and simultanously create set and get functions for complex structures.

- 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

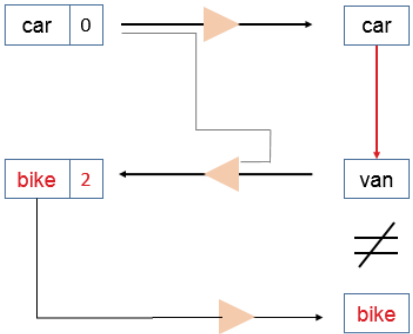
Definition

Def. A lense l from concrete (larger) representation (type) C to an abstract (smaller) representation (type) A comprises a partial function $l \nearrow\colon A \to C$ (`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]` (access 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!

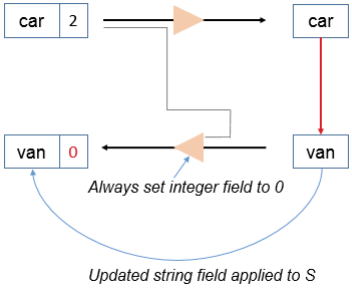
Put-Get Law

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

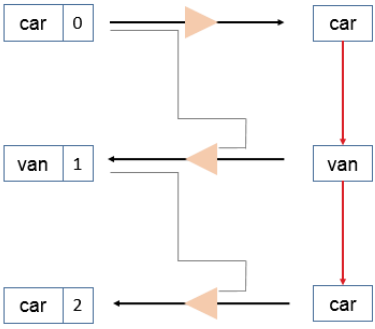
For a lense l and each concrete value c we have: $l \searrow (l \nearrow (c))(c) = c$

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

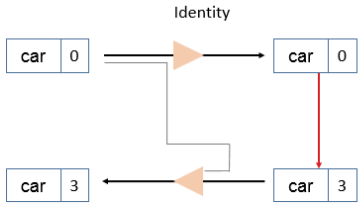
For a lens l, and all values c, a, and a' we have: $l \searrow (a')(l \searrow (a)(c)) == l \searrow (a', c)$

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)`?

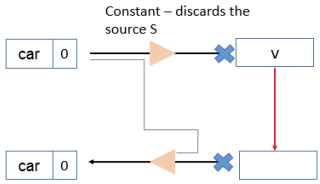
In Scala syntax:

```
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)`?

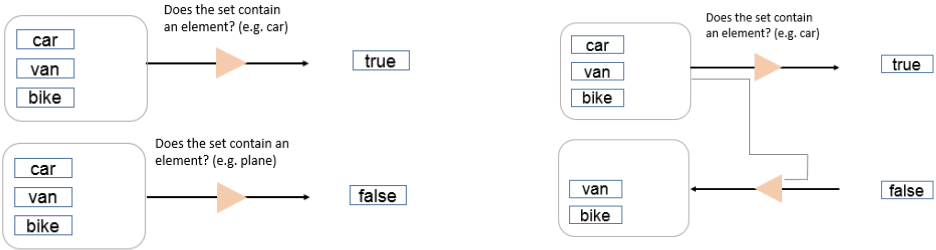
In Scala syntax:

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

Total, not well-behaved.

Set Membership (Contains)

An example Lens



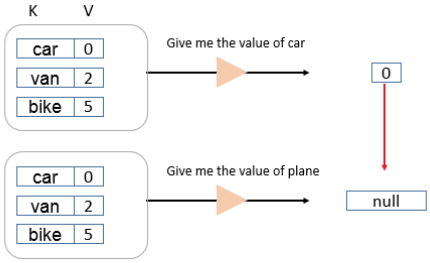
In Scala syntax:

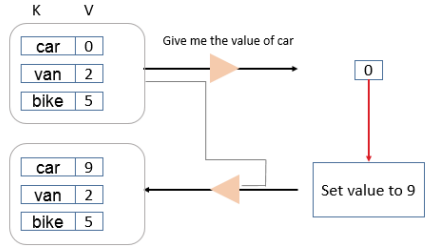
```
def contains[T] (x: T) =
  Lens[Set[T],Boolean]
    (get =_.contains (x))
    (set =b =>c =>if (b) c.incl (x) else c.excl (x))
```

Total, very well-behaved.

Index (in a map)

An example Lens



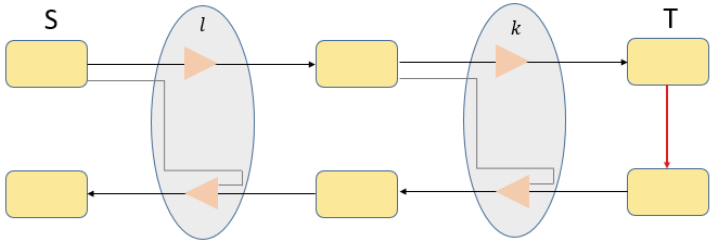


In Scala syntax:

```
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 _)
5 }
```

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 _)
6  }
```

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 (implicits), 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