Dependency Injection Without the Gymnastics

Functional Programming Applied

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In this talk, we take a look at some specific Functional Programming patterns that regularly arise in everyday programming. These patterns are used to solve the same problems that DI attempts to by decoupling data types from their dependencies.

We explore the algebraic properties of these techniques and discover how they give rise to useful programming properties that we may apply in our typical work. This talk focuses on the techniques rather than any particular programming language, since none of these techniques are monopolized by a specific language. Various programming languages will be used for demonstration to emphasize this point; Haskell, Scala, Java and C# for example.

The audience should expect to walk away from this talk with a slight amount of bewilderment, a clear understanding of some FP subjects, but importantly, with the invigorated inspiration to explore these techniques further.

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Introduction

- Runar went deep into the Reader monad to discuss dependency injection[1]
- I am going to fly-by the Reader monad, then enter a rapid climb, levelling out at the `ReaderWriterStateT` monad transformer.
- I am going to ask you to hold a *lot more* in your head, inspiring you to follow it up with applications later.
- We will use mostly Scala for code listings.
- You may get a little uncomfortable. This is a *good thing*.

The Real Goal

The real goal is:

- to introduce you to some interesting and useful data structures
- to introduce you to a not-so-beginner view of a programming technique (I like living on the edge — do you?) called *pure functional programming*
- to achieve these two goals by appealing to a problem you are likely already familiar with (DI)
- it's going to look a bit like we are picking on DI, though this is not a goal (it does a spectacular job of that on its own)

What is Dependency Injection?

The Essence of DI

- Dependency injection often comes in two general forms:
  1. Applications require a read-only *context*, which is initialised before the dependent application starts.
  2. Applications require a read/write *context*, which is initialised before the dependent application starts.
- In both cases, the DI runtime guarantees that the context initialisation will occur at the right time — this is the essential promise of dependency injection.[2]
- The rest is uninteresting ceremony.

[1] Dead-Simple Dependency Injection http://lanyrd.com/2012/nescala/sqygc/
[2] Dependency injection is just socially-acceptable global variables — Anon

Gymnastics

- ‹Personally/›, I have seen *all sorts* of ‹gymnastics sorts="all"/› in an effort to provide this guarantee.
- After all, if this guarantee is broken at any time, the program **crashes spectacularly**.
- Let's be honest, it never works consistently — it's just a global variable with all the usual dangers.
- OK then, pass arguments through explicitly — bit clumsy innit?

Generalising Programs

A Trivial Scala Program

```
val a = e1
val b = e2(a)
val c = e3(a, b)
val d = e2(b)
```

- Remove the `val` keyword.
- Replace the = symbol with `<-`
- Wrap the program in `for` and `yield` keywords.

A Trivial Program in Identity

```
for {
  a <- e1
  b <- e2(a)
  c <- e3(a, b)
  d <- e2(b)
} yield d
```

We can transform our programs like this by wrapping values (`e1`, etc.) in `Identity`.

```
case class Identity[A](a: A) {
  def map[B](f: A => B): Identity[B] = Identity(f(a))
  def flatMap[B](f: A => Identity[B]): Identity[B] = f(a)
}
```

Add a Bit of Context

- OK, so if `e1` was of the type `Int`, it now becomes `Identity[Int]` and so on.
- but `Identity` is quite a boring context.
- Are there more structures that add more interesting context to values of any type?

Reader

```
case class Reader[A](rd: Context => A) {
  def map[B](f: A => B): Reader[B] =
      Reader(f compose rd)
  def flatMap[B](f: A => Reader[B]): Reader[B] =
```

```
      Reader(c => f(rd(c)) rd c)
}
```

- Now values that were once typed `T` becomes values with the type `Reader[T]`.
- In other words, these values can access a `Context` to produce their result.
- This concept of "accepting an argument" is often referred to as *Inversion of Control*.
- …and most importantly…

Reader Monad

```
for {
  a <- e1
  b <- e2(a)
  c <- e3(a, b)
  d <- e2(b)
} yield d
```

- …the program remains unchanged.
- Here, we are computing values with a context available, but *without explicitly passing it through our program*.

Example

A simple enough example?

- Can we find an example good enough to demonstrate the point, but small enough to fit on slides?! :)
- We can do this *for any value* in our context.
- Let our context be a hostname and port pair, `(String, Int)`.
- We are going to *inject* this read-only dependency into our program, so that:
  - values that require access to it can do so
  - the dependency is not explicitly passed around our program
  - our program maintains *referential transparency — no variables*, and therefore, the benefits that follow

Set up Libraries

- ```
  // Hostname+port reader
  case class CReader[A](rd: (String, Int) => A) {
    def map(f: A => B): CReader[B] =
      sys.error("todo")
    def flatMap(f: A => CReader[B]): CReader[B] =
      sys.error("todo")
  }
  ```

- ```
  // Ignore the context, lift into CReader
  def point[A](a: => A): CReader[A] =
      CReader(_ => a)
  ```

Usage example

```
for {
  _ <- log("connect: %s:%s")
  w <- getWibble
  val v = w modL biggen
  u <- setWibble(v)
  _ <- log("disconnect %s:%s")
} yield u
```

Some important points of note:

- `log: String => CReader[X]` with a catch!
- `getWibble/setWibble: CReader[Wibble]`
- `modL` is a *lens operator* for working with immutable records such as `Wibbles`.

...and it's not all that different to our everyday programming

Example 1. The same code in C#/LINQ using monad comprehension syntax

```
from a in Log("connect: %s:%s")
from w in GetWibble
from u in SetWibble(w.ModL(Biggen))
from b in Log("disconnect %s:%s")
select u
```

- What Scala calls:
  - `flatMap`, C# calls `SelectMany`
  - `map`, C# calls `Select`

...and in Haskell

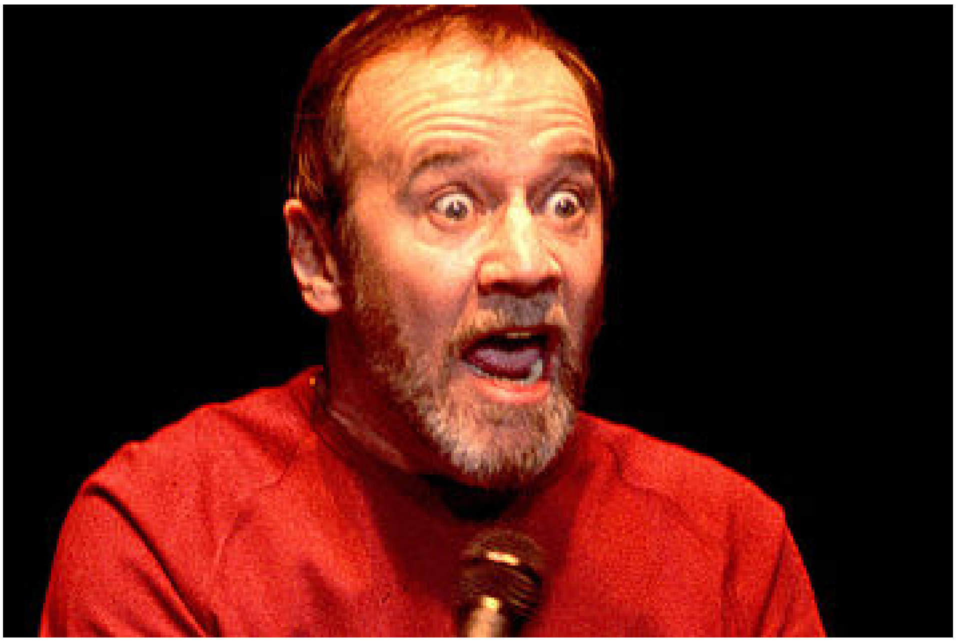
Example 2. Using Haskell monad comprehension syntax

```
do log "connect: %s:%s"
   w <- getWibble
   let v = w modL biggen
   u <- setWibble v
   log "disconnect %s:%s"
   return u
```

State

But then the TPS report comes in from the senior enterprise architellij...

... and the product manager wants the ability to allow the user to dynamically synergise the port number on the fly



"Oh no! More stuff!" — George Carlin

Injecting a Read/Write Context

- We have seen a read-only Context (called Reader) over a value (A)

  `Context => A`

  - is a functor — has a useful `map` method
  - is a monad — has a useful `flatMap` method

- Read/Write Context (called State) over a value (A)

  `Context => (A, Context)`

State Monad

`State` is a monad too!

```
case class State[Cx, A](run: Cx => (A, Cx)) {
  def map[B](f: A => B): State[Cx, B] =
      State(x => {
        val (a, t) = run(x)
        (f(a), t)
      })
  def flatMap[B](f: A => State[Cx, B]): State[Cx, B] =
      State(x => {
        val (a, t) = run(x)
        f(a) run t
      })
}
```

Better fix the program then innit?

```
for {
  _ <- log("connect: %s:%s")
```

```
  w <- getWibble
  val v = w modL biggen
  u <- setWibble(v)
  _ <- log("disconnect %s:%s")
} yield u
```

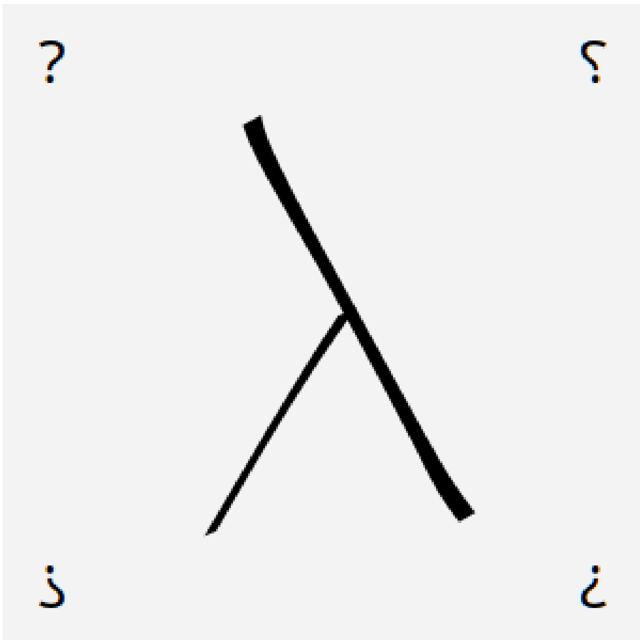
- The program remains **unchanged** due to generalisation.
- However, now we can add our context-writes *without introducing in-place variables.*

Add a Context Write

We can change the port as the program runs, because we can change to a read-write context easily and without affecting orthogonal program parts.

```
for {
  _ <- log("connect: %s:%s")
  _ <- setPort(80) // context-write
  w <- getWibble
  val v = w modL biggen
  u <- setWibble(v)
  _ <- log("disconnect %s:%s")
} yield u
```

Hammer Time



Now is a good time to pause for questions.

Contexts All the Way Down

Transformers

- We have seen read-only contexts and read-write contexts, but what about others?
  - Nullability (`Option`)
  - Non-determinism (`List`)

    - Logging (`Writer`)
    - I/O
    - Exception handling (`Either[Throwable, _]`)
- Importantly, what if we want to *combine* two contexts to create a new context?
    - We might want to read a context and compute a nullable (`Option`) value. Can we combine these two contexts?

ReaderT

- Was:

```
case class Reader[A](rd: Context => A)
```

- Now:

```
case class ReaderT[F[_], A](rd: Context => F[A])
```

    - `ReaderT` has a `map` method if `F` has a `map` method
    - `ReaderT` has a `flatMap` method if `F` has a `flatMap` method
    - `type Reader[A] = ReaderT[Identity, A]`

Stacking It Up

- Remember those `log` statements? [1] [2] [3] They have `F=Writer` stacked in the context — just another context!
- Not only are we injecting with composition, but injecting into a stack of contexts that can be chosen specific to the problem at hand.
- We can do it with read-write contexts (`State`) too.

```
case class StateT[Cx, F[_], A](run: Cx => F[(Cx, A)])
type State[Cx, A] = StateT[Cx, Identity, A]
```

… wait a minute … if `Option` has `flatMap` …

```
case class OptionState[Cx, F[_], A](run: StateT[Cx, Option, A])
```

- Again, our program client remains unchanged, running through its for-comprehension.
- Reader has `flatMap` too!

```
case class ReaderState[F[_], A](run: StateT[Cx, Reader, A])
```

- We can stack *indefinitely*, thus injecting dependencies arbitrarily and with solid library support.

Sceptical?

- You are now probably one of three people:

- WTF is this guy smokin'? Give me my XML, variables, bugs, frameworks and really big JAR files back right now!
- I wonder what you just said; can I see some code now?
- *yawn* seen it all before, been doing it for years, when is lunch?

- To understand this subject more deeply, there are plenty of resources and people to help — just ask!

Reader/Writer/State Transformer

The Essence of Injecting Dependencies

Putting it All Together

- Dependency Injection is, quite concisely, a specialisation of the reader/writer/state monad transformer.
- The *what what* transformer?
- The transformer that is stacked with `Reader`, `Writer`, `State` and an arbitrary context

Reminder

- `case class Reader[R, A](f: R => A)`
- `case class Writer[W, A](w: (W, A))`
- `case class State[S, A](f: S => (A, S))`
- Reader+Writer+State?

RWS Transformer in Scala

```
case class ReaderWriterStateT[R, W, S, F[_], A](
  run: (R, S) => F[(W, A, S)]
) {
  def map[B](f: A => B)(implicit F: Functor[F])
  : ReaderWriterStateT[R, W, S, F, B] =
    ReaderWriterStateT {
      case (r, s) => F.map(run(r, s)) {
        case (w, a, s) => (w, f(a), s)
      }
    }

  def flatMap[B](f: A => ReaderWriterStateT[R, W, S, F, B])
                (implicit F: FlatMap[F], W: Semigroup[W])
  : ReaderWriterStateT[R, W, S, F, B] =
    ReaderWriterStateT {
      case (r, s) => F.flatMap(run(r, s)) {
        case (w1, a, s1) => F.map(f(a) run (r, s1)) {
          case (w2, b, s2) => (W.op(w1, w2), b, s2)
        }
      }
    }
}

object ReaderWriterStateT {
  type ReaderWriterState[R, W, S, A] =
```

```
  ReaderWriterStateT[R, W, S, Id, A]
}

case class ReaderT[A, F[_], B](
                                  rd: A => F[B]
                                  ) {
  def rws[W, S](implicit F: Functor[F], W: Monoid[W])
  : ReaderWriterStateT[A, W, S, F, B] =
    ReaderWriterStateT {
      case (r, s) => F.map(rd(r))(
        (W.id, _, s)
      )
    }
}

object ReaderT {
  type Reader[A, B] =
  ReaderT[A, Id, B]
}

case class WriterT[W, F[_], A](
                                  wx: F[(W, A)]
                                  ) {
  def rws[R, S](implicit F: Functor[F])
  : ReaderWriterStateT[R, W, S, F, A] =
    ReaderWriterStateT {
      case (r, s) => F.map(wx){
        case (w, a) => (w, a, s)
      }
    }
}

object WriterT {
  type Writer[W, A] =
  WriterT[W, Id, A]
}

case class StateT[S, F[_], A](
                                 st: S => F[(A, S)]
                                 ) {
  def rws[W, R](implicit F: Functor[F], W: Monoid[W])
  : ReaderWriterStateT[R, W, S, F, A] =
    ReaderWriterStateT {
      case (r, s) => F.map(st(s)){
        case (a, s) => (W.id, a, s)
      }
    }
}

object StateT {
  type State[S, A] =
  StateT[S, Id, A]
}

case class Id[A](a: A)

object Id {
  implicit val IdFlatMap: FlatMap[Id] =
```

```
    new FlatMap[Id] {
      def fmap[A, B](f: A => B) =
        i => Id(f(i.a))
      def bind[A, B](f: A => Id[B]) =
        i => f(i.a)
    }
}

trait Functor[F[_]] {
  def fmap[A, B](f: A => B): F[A] => F[B]
  def map[A, B](a: F[A])(f: A => B): F[B] =
    fmap(f)(a)
}

trait FlatMap[F[_]] extends Functor[F] {
  def bind[A, B](f: A => F[B]): F[A] => F[B]
  def flatMap[A, B](a: F[A])(f: A => F[B]): F[B] =
    bind(f)(a)
}

trait Semigroup[A] {
  def op(a1: A, a2: A): A
}

trait Monoid[A] extends Semigroup[A] {
  def id: A
}
```

RWS Transformer in Haskell

```
newtype ReaderWriterStateT r w s f a =
  ReaderWriterStateT {
    run :: (r, s) -> f (w, a, s)
  }

instance Functor f =>
  Functor (ReaderWriterStateT r w s f) where
  fmap f (ReaderWriterStateT x) =
    ReaderWriterStateT $
      fmap (\(w, a, s) -> (w, f a, s)) . x

instance (FlatMap f, Semigroup w) =>
  FlatMap (ReaderWriterStateT r w s f) where
  flatMap f (ReaderWriterStateT x) =
    ReaderWriterStateT $ \(r, s) ->
      flatMap (\(w1, a, s1) ->
        fmap (\(w2, b, s2) ->
          (op w1 w2, b, s2))
          (run (f a) (r, s1))) (x (r, s))

type ReaderWriterState r w s a =
  ReaderWriterStateT r w s Id a

newtype ReaderT a f b =
  ReaderT { rd :: a -> f b }

rwsR (ReaderT f) =
  ReaderWriterStateT $ \(r, s) ->
```

```
    fmap (\z -> (identity, z, s)) (f r)

type Reader a b =
  ReaderT a Id b

newtype WriterT w f a =
  WriterT { wx :: f (w, a) }

rwsW (WriterT x) =
  ReaderWriterStateT $ \(r, s) ->
    fmap (\(w, a) -> (w, a, s)) x

type Writer w a =
  WriterT w Id a

newtype StateT s f a =
  StateT { st :: s -> f (a, s) }

rwsS (StateT f) =
  ReaderWriterStateT $ \(r, s) ->
    fmap (\(a, s) -> (identity, a, s)) (f s)

type State s a =
  StateT s Id a

newtype Id a = Id a

instance Functor Id where
  fmap f (Id a) = Id (f a)

instance FlatMap Id where
  flatMap f (Id a) = f a

class Functor f => FlatMap f where
  flatMap :: (a -> f b) -> f a -> f b

class Semigroup a where
  op :: a -> a -> a

class Semigroup a => Monoid a where
  identity :: a
```

A. Tony Morris — PGP Key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