Monadic Design Patterns for the Web

Episode IV - Code Talks!

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Outline

- Inheritance and reuse
- The Monadic API as a view
- Enough structure to support multiple views
- Conway Games
- Poking a hole in Conway
- Reuse again?

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Acknowledgement

Scala is a BIG tent. While everybody else is scaling the web and DSLing, lgm is abstracting Conway games over arbitrary monads.

James Iry, recent tweet

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Inheritance and reuse

- What does reuse really mean?
- Proposal -- we can reuse code just when we know we can substitute that code for other code that "does the same thing"
- Types give us a first approximation of "does the same thing" -- but in many cases are not enough -- we usually need some additional context information

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Inheritance and reuse

- For example, we could say that Sets *are* functions from the Universe from which they are drawn to Boolean
- In code: Set[A] ≈ A => Boolean
- But this actually presumes a great deal about what we mean by function, Set and Universe

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Inheritance and reuse

- In a world of higher-order functions it is easy to reify our assumptions:

```
trait SetsCanBeFunction[S,T] {
    def asFunction( s : Set[S] ) : S => T
}
trait SetsCanBeTotalFunctions[S]
    extends SetsCanBeFunctions[S,Boolean]
```

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Inheritance and reuse

- But also

trait SetsCanBeFuzzy[S]

extends SetsCanBeFunctions[S,Double]

trait SetsCanBePartialFunctions[S]

extends SetsCanBeFunctions[S,Option[Boolean]]

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Inheritance and reuse

- Is-a relationships are more often than not meaningful or applicable *in a context*
- With the higher-order approach, we can easily reify the context and have a representative of our assumptions
- Inheritance sublimates the context of an is-a relationship, eliminating the representative of our assumptions

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The Monadic API as a View

- The view from here is pretty nice!
- Structures like List, Set, Tree, ... are *not* monads -- but they can be viewed as having monadic structure

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The Monadic API as a View

shape

wrap

```
trait Monad[M[_]] {

  def unit [A] ( a : A ) : M[A]

  def bind [A,B] ( ma : M[A], fn : A => M[B] ) : M[B]

}
```

jelly roll

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The Monadic API as a View

```
class ListM[A] extends Monad[List] {

  override def unit [S] ( s : S ) : List[S] = { List[S]( e ) }

  override def bind [S,T] ( ls : List[S], fn : S => List[T] ) = {

    ( ( Nil : List[T] ) /: ls )( { ( acc, e ) => { acc ++ f( e ) } } )

  }

}
```

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The Monadic API as a View

- With these containers -- together with the constraints like functoriality -- it's harder to see how there might be different interpretations of the monadic API -- it's all so canonical!

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Enough structure to support multiple views

- A container with components that are containers is just the right sort of device to illustrate this point

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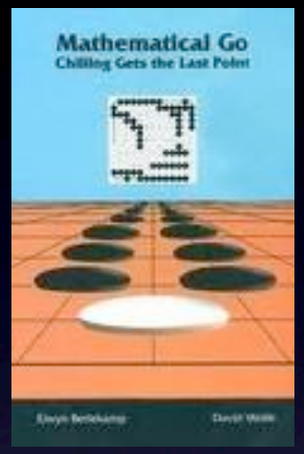
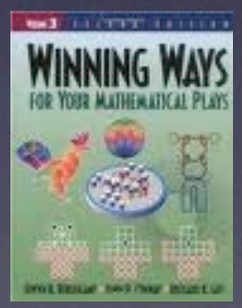
Conway Games



- The 0 game -- i offer you the first move...



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Conway Games

- A game captures the options of Player and Opponent
- An option is a move to a new position in which Player and Opponent have new options

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Conway Games

Actually, these are the droids you're looking for!

```
trait ConwayGame {
    def left : Set[ConwayGame]
    def right : Set[ConwayGame]
}
```

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Conway Games

```
case object EmptyGame
      extends ConwayGame {
   override def left : Set[ConwayGame] =
   Set.empty

   override def right : Set[ConwayGame] =
   Set.empty

}
```

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Conway Games

```
case class Game(
    override val left : Set[ConwayGame],
    override val right : Set[ConwayGame]
) extends ConwayGame
```

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Conway Games

```
val cgZero = EmptyGame

val cgOne = Game( Set( cgZero ), Set.empty )

val cgTwo = Game( Set( cgOne ), Set.empty )

...

val cgMinusOne = Game( Set.empty, Set( cgZero ) )

...

 val cgOneHalf = Game( Set( cgOne ), Set( cgZero ) )
```

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Conway Games

```
trait Calculator {

    def minus( g : ConwayGame ) : ConwayGame = {

        g match {

            case EmptyGame => EmptyGame

            case Game( gL, gR ) =>

            Game( gR.map( minus ), gL.map( minus ) )

        }

    }
```

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Conway Games

def add(g1 : ConwayGame, g2 : ConwayGame) : ConwayGame

def multiply(g1 : ConwayGame, g2 : ConwayGame) : ConwayGame

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Conway's notation

$0 = \{ \mid \}$

$1 = \{ 0 \mid \} = \{ \{ \mid \} \mid \}$

$2 = \{ 1 \mid \} = \{ \{ \{ \mid \} \mid \} \mid \}$

...

$G = \{ G^L, \ldots \mid G^R, \ldots \}$

$-G := \{ -G^R \mid -G^L \}$

$G1 + G2 := \{ G1^L + G2, G2^L + G1 \mid G1^R + G2, G2^R + G1 \}$

Can you say 'DSL'?
i knew you could!

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Poking (a hole in) Conway

- Conway Games are as pure as Sets
- Ordinary Set Theory offers no place to put data! Sets are either empty or contain other Sets.
- The same is true for ConwayGames

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Poking (a hole in) Conway

- Just as we understand intuitively what we mean by Set[A] ...
- We can have an intuitive understanding of ConwayGame[A]
  - Yet, when it comes to arithmetic, we have to proceed with caution!

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Poking (a hole in) Conway

```
trait GenConwayGame[A] {
    left : Set[Either[A,GenConwayGame[A]]]
    right : Set[Either[A,GenConwayGame[A]]]
}
```

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Poking (a hole in) Conway

- When we negate, add or multiply these widgets we get into situations where we are asked to combine A's, and GenConwayGame[A]'s.
- We defer and reify! This is the basic power of monads!

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Poking (a hole in) Conway

- From a the point of view of the Monadic API we have two containers -- left and right -- that would support monadic structure
- We have two views!
    - unit wraps A's into left component
    - unit wraps A's into right component
    - bind is forced to do the same thing in either view

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Poking (a hole in) Conway

- This kind of generalization and the ease with which we make it is one of the real contributions that Computer Science makes back to society
- It invites even better questions, for look:

```
trait GenConwayGame[M[_],A] {
    left : M[Either[A,GenConwayGame[A]]]
    right : M[Either[A,GenConwayGame[A]]]
}
```

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Poking (a hole in) Conway

- It turns out our calculator code works as is with this structure!
- This means we can build notions of quantity as rich as the Field of the Reals over arbitrary monads!

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Reuse again?

So, i took it apart and put it back together, but i'm not sure what to do with these?

- In Scala Set[A] inherits from A => Boolean
- This means that the variance constraints of List[A] and Set[A] differ!
- This is not consistent!
- It meant i had to write my own Set for this talk

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What does this have to do with Monadic Design Patterns for the Web?

- Scaling the web isn't just about volume or load or sheer numbers
- Scaling the web is as much about complexity
- You can have the most scalable architecture ever invented, but if nobody can program to it, it's not useful

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Location, location, location!

- Conway's construction actually gives us a generic notion of location
- Once we see it from the Monadic vantage point we see that it can be compared with Huet's proposal for location

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