MOVE OVER FREE MONADS:
MAKE WAY FOR FREE APPLICATIVES!

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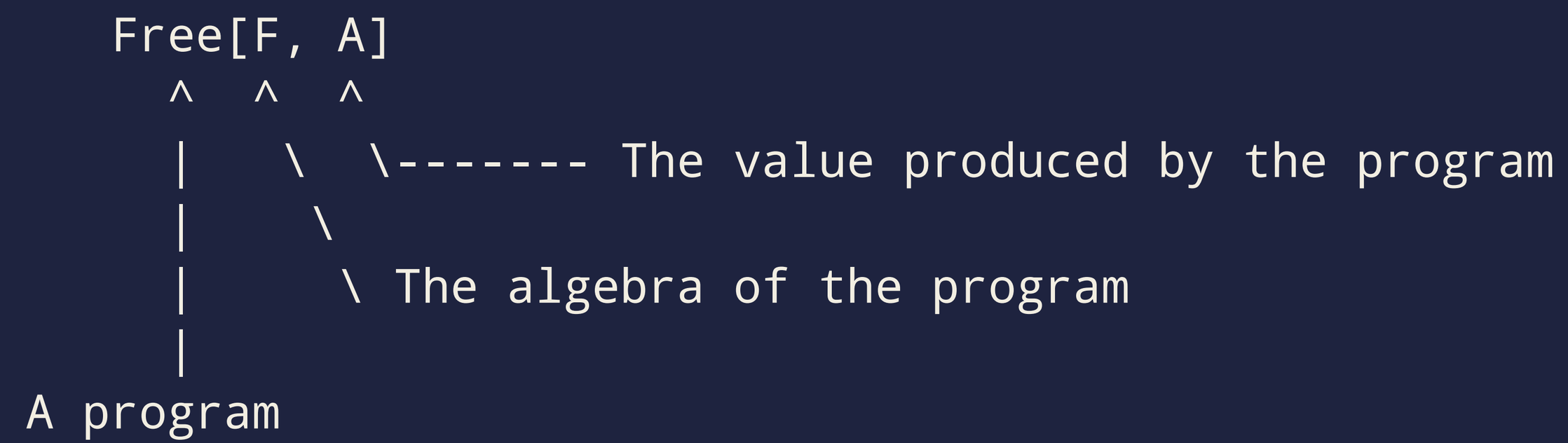
http://github.com/jdegoes/scalaworld-2015

FREE MONADS

Free Monads: Don't build a program. Build a description of a program.

- Easier to transform, compose, reason about
- Extensible effects
- Reflection without remorse
- Aspect-oriented programming

FREE MONADS: THE PROGRAM PERSPECTIVE



FREE MONADS: THE PROGRAM PERSPECTIVE

```
sealed trait Console[A]
case class ReadLine [A](value: String -> A) extends Console[A]
case class PrintLine[A](line: String, value: A) extends Console[A]
...
type Dsl[A] = Free[Console, A]

def readLine                  : Dsl[String] = ReadLine(identity)
def printLine(line: String): Dsl[Unit]   = PrintLine(line, ())

val program = for {
  line <- readLine
  _    <- printLine("You wrote: " + line)
} yield ()
```

THE TROUBLE WITH MONADS

```
trait Monad[F[_]] {
  ...
  def bind[A, B](fa: F[A])(f: A => F[B]): F[B]
                     ^        ^    ^      ^
                     |        |    |      |
                     |        |    |      |
                     |        |  Second   |
                     |        | Program   |
                     |        |           |
                     |  Runtime Value     |
                     |                    |
               First Program        Result Program
}
```

Monads embody the essence of sequential computation: a program can depend on a value produced by a previous program.

THE TROUBLE WITH FREE MONADS

The structure of monadic programs is dynamic. `Free` monad programs can only be interpreted, not introspected and transformed prior to interpretation.

```
def bind[A, B](fa: F[A])(f: A => F[B]): F[B]
                           ^
                           |
                           |
                           |
                           |
                    !@!#%!@!!
```

APPLICATIVES TO THE RESCUE?

Functor → Applicative → Monad

```
trait Applicative[F[_]] {
  ...
  // Easier: F[A] => F[B] => F[(A, B)]
  def ap[A, B](ff: F[A => B])(fa: F[A]): F[B]
                   ^              ^      ^
                   |              |      |
                   |           Second    |
                   |           Program   |
             First Program               |
                                         |
                                  Result Program
}
```

No program depends on any runtime value: the structure is static.

BUT....

Applicatives are, obviously, strictly less powerful than Monads.

```
(doX(a) |@| doY(b) |@| doZ(c))(doResults(_, _, _))
```

Static structure has a cost.

FREE APPLICATIVES

- Record the structure of applicative composition.
- Interpret it later in any way.

```
sealed trait FreeAp[F[_], A]
                    ^
                    |
          Any * -> * (not even functor!)
```

CONFREE: CONFIGURATION LIBRARY

Can we build an Applicative language for describing the configuration needs of our application?

CONFREE: CONFIGURATION LIBRARY

ALGEBRA[1]

```
object algebra {
  sealed trait ConfigF[A]

  case class ConfigInt   [A](field: String, value: Int     => A) extends ConfigF[A]
  case class ConfigFlag  [A](field: String, value: Boolean => A) extends ConfigF[A]
  case class ConfigPort  [A](field: String, value: Int     => A) extends ConfigF[A]
  case class ConfigServer[A](field: String, value: String  => A) extends ConfigF[A]
  case class ConfigFile  [A](field: String, value: String  => A) extends ConfigF[A]
  case class ConfigSub   [A](field: String, value: FreeAp[ConfigF, A]) extends ConfigF[A]
}
```

[1] See Appendix A.

CONFREE: CONFIGURATION LIBRARY

DSL

```
object dsl {
  import algebra._

  type Dsl[A] = FreeAp[ConfigF, A]

  private def lift[A](value: ConfigF[A]): Dsl[A] = FreeAp.lift[ConfigF, A](value)

  def int   (field: String): Dsl[Int]     = lift(ConfigInt   (field, identity))
  def flag  (field: String): Dsl[Boolean] = lift(ConfigFlag  (field, identity))
  def port  (field: String): Dsl[Int]     = lift(ConfigPort  (field, identity))
  def server(field: String): Dsl[String]  = lift(ConfigServer(field, identity))
  def file  (field: String): Dsl[String]  = lift(ConfigFile  (field, identity))
  def sub[A](field: String)
            (value: Dsl[A])               = lift(ConfigSub   (field, value))
}
```

CONFREE: CONFIGURATION LIBRARY

USAGE

```
object example {
  ...
  import dsl._

  case class AuthConfig(port: Int, host: String)
  case class ServerConfig(logging: Boolean, auth: AuthConfig)

  val authConfig   = (int("port") |@| server("host"))(AuthConfig)
  val serverConfig = (flag("logging") |@| sub("auth")(authConfig))(ServerConfig)
  ...
}
```

CONFREE: CONFIGURATION LIBRARY

INSTANT HELP

```
def genHelp[A](config: Dsl[A]): String = ...

scala> genHelp(serverConfig)
res10: String =
"auth     - a sub-configuration
  host    - a server address
  port    - an integer
logging   - a boolean flag
"
```

CONFREE: CONFIGURATION LIBRARY

INSTANT DESERIALIZATION

```
def genDecode[A](config: Dsl[A]): DecodeJson[A] = ...

val serverConfigJson =
      Json("logging" -> jTrue,
           "auth" -> Json("port" -> jNumberOrNull(2020),
                          "host" -> jString("localhost")))

scala> genDecode(serverConfig).decodeJson(serverConfigJson)
res11: argonaut.DecodeResult[confree.example.ServerConfig] =
  DecodeResult(\/-(ServerConfig(true,AuthConfig(2020,localhost))))
```

CONFREE: CONFIGURATION LIBRARY

HOW THE SAUSAGE IS MADE

```
def genDecode[A](config: Dsl[A]): DecodeJson[A] =
  config.foldMap(new NaturalTransformation[ConfigF, DecodeJson] {
    def apply[A](value: ConfigF[A]): DecodeJson[A] = DecodeJson(json => value match {
      case ConfigInt   (n, v) => (json --\ n).as[Int]    .map(v)
      case ConfigFlag  (n, v) => (json --\ n).as[Boolean].map(v)
      case ConfigPort  (n, v) => (json --\ n).as[Int]    .map(v)
      case ConfigServer(n, v) => (json --\ n).as[String] .map(v)
      case ConfigFile  (n, v) => (json --\ n).as[String] .map(v)
      case ConfigSub   (n, v) =>  for {
                                    sub <- (json --\ n).as[Json]
                                    a   <- genDecode(v).decodeJson(sub)
                                  } yield a
    })
  })
```

CONFREE: CONFIGURATION LIBRARY

HOW THE SAUSAGE IS MADE

```
case class HelpState(help: String = "", indent: Int = 0) {
  def --> (h: String): HelpState =
    copy(help = help + (0 until indent * 2).foldLeft[String]("")((a, _) => a + " ") + h + "\n")

  def indented: HelpState = copy(indent = indent + 1)
  def dedented: HelpState = copy(indent = indent - 1)
}
```

CONFREE: CONFIGURATION LIBRARY

HOW THE SAUSAGE IS MADE

```
def genHelp[A](config: Dsl[A]): String = {
  type G[A] = State[HelpState, A]

  def genHelp0[A](config: Dsl[A]): G[A] = {
    config.foldMap(new NaturalTransformation[ConfigF, G] {
      def apply[A](value: ConfigF[A]): G[A] = value match {
        case ConfigInt   (n, v) => State.modify[HelpState](_ --> (n + "\t - an integer"      )) *> v(0).point[G]
        case ConfigFlag  (n, v) => State.modify[HelpState](_ --> (n + "\t - a boolean flag"  )) *> v(false).point[G]
        case ConfigPort  (n, v) => State.modify[HelpState](_ --> (n + "\t - a port number"   )) *> v(0).point[G]
        case ConfigServer(n, v) => State.modify[HelpState](_ --> (n + "\t - a server address")) *> v("").point[G]
        case ConfigFile  (n, v) => State.modify[HelpState](_ --> (n + "\t - a file path"     )) *> v("").point[G]
        case ConfigSub   (n, v) =>  for {
                                      _ <- State.modify[HelpState](_ --> (n + "\t - a sub-configuration"))
                                      _ <- State.modify[HelpState](_.indented)
                                      a <- genHelp0(v)
                                      _ <- State.modify[HelpState](_.dedented)
                                    } yield a
      }
    })
  }

  genHelp0(config).exec(HelpState()).help
}
```

YUCK!!!!!!!

FINALLY TAGLESS: PAIN-FREE(AP)

```
object algebra {
  sealed trait AsmF[F[_]] extends Applicative[F] {
    def push(v: Int): F[Unit]

    def pop: F[Int]

    def sum: F[Int]

    def mul: F[Int]
  }
}
```

FINALLY TAGLESS: PAIN-FREE(AP)

```
object dsl {
  import algebra._

  sealed trait Dsl[A] {
    def apply[F[_]: AsmF]: F[A]
  }

  def push(v: Int): Dsl[Unit] = new Dsl[Unit] { def apply[F[_]: AsmF] = implicitly[AsmF[F]].push(v) }

  def pop: Dsl[Int] = new Dsl[Int] { def apply[F[_]: AsmF] = implicitly[AsmF[F]].pop }

  def sum: Dsl[Int] = new Dsl[Int] { def apply[F[_]: AsmF] = implicitly[AsmF[F]].sum }

  def mul: Dsl[Int] = new Dsl[Int] { def apply[F[_]: AsmF] = implicitly[AsmF[F]].mul }

  implicit val ApplicativeDsl: Applicative[Dsl] = new Applicative[Dsl] {
    def point[A](a: => A): Dsl[A] = new Dsl[A] { def apply[F[_]: AsmF] = a.point[F] }
    def ap[A, B](fa: => Dsl[A])(f: => Dsl[A => B]): Dsl[B] = new Dsl[B] {
      def apply[F[_]: AsmF] = fa.apply[F] <*> f.apply[F]
    }
  }
}
```

FINALLY TAGLESS: PAIN-FREE(AP)

```
def program =
  push(1) *>
  push(2) *>
  sum     *>
  push(9) *>
  mul
```

FINALLY TAGLESS: PAIN-FREE(AP)

```
def print[A](p: Dsl[A]): String = {
  type Printer[A] = String

  p.apply(new AsmF[Printer] {
    def point[A](a: => A): Printer[A] = ""

    def ap[A, B](fa: => Printer[A])(f: => Printer[A => B]): Printer[B] = f + fa

    def push(v: Int) = "push " + v + "\n"

    def pop = "pop\n"

    def sum = "sum\n"

    def mul = "mul\n"
  })
}
```

FINALLY TAGLESS: PAIN-FREE(AP)

```
def evaluate[A](p: Dsl[A]): A = {
  type EvaluatorState = List[Int]

  type Evaluator[A] = State[List[Int], A]

  p.apply(new AsmF[Evaluator] {
    def point[A](a: => A): Evaluator[A] = a.point[Evaluator]

    def ap[A, B](fa: => Evaluator[A])(f: => Evaluator[A => B]): Evaluator[B] = fa <*> f

    def push(v: Int) = State.modify[EvaluatorState](v :: _)

    def pop = State.get[EvaluatorState].map(_.head)

    def sum = for {
      l <- State.get[EvaluatorState]
      (x1 :: x2 :: Nil, ys) = l.splitAt(2)
      v = x1 + x2
      _ <- State.put[EvaluatorState](v :: ys)
    } yield v

    def mul = for {
      l <- State.get[EvaluatorState]
      (x1 :: x2 :: Nil, ys) = l.splitAt(2)
      v = x1 * x2
      _ <- State.put[EvaluatorState](v :: ys)
    } yield v
  }).eval(Nil)
}
```

EXPRESSIVE POWER OF FREE APPLICATIVES

- Parsers - Auto-complete, optimization, & even lookahead!
- Codecs
- Simple programs
- Static "Runtime Branching" - `Alternative`, fixed equivalence
- ???

INTUITION FOR FREE FUNCTOR HIERARCHY

- Free Functors: Programs that Change Values
- Free Applicatives: Programs that Build Data
- Free Monads: Programs that Build Programs

THANK YOU!

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APPENDIX A: GADTS IN SCALA

```
sealed trait ConfigF[A]

case class ConfigInt   (field: String) extends ConfigF[Int]
case class ConfigFlag  (field: String) extends ConfigF[Boolean]
case class ConfigPort  (field: String) extends ConfigF[Int]
case class ConfigServer(field: String) extends ConfigF[String]
case class ConfigFile  (field: String) extends ConfigF[String]
case class ConfigSub   [A](field: String, value: FreeAp[ConfigF, A])   extends ConfigF[A]

def fail[A](v: ConfigF[A]) = {
  case ConfigInt(f) => // A must be Int!
  ...
}
```