

Categories in the wild

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Naked interface

```
trait Cassandra {  
  def prepare(statement: String): PreparedStatement  
  def prepare(statement: RegularStatement):  
    PreparedStatement  
  def execute(statement: String): Unit  
  def execute(statement: Statement): Unit  
}
```

Wrapped interface

```
trait Cassandra {  
  def prepare(statement: String): F[PreparedStatement]  
  def prepare(statement: RegularStatement):  
    F[PreparedStatement]  
  def execute(statement: String): F[Unit]  
  def execute(statement: Statement): F[Unit]  
}
```

Map

```
map: (X => Y) => F[X] => F[Y]
```

```
// map((x: X) => x)(y) === y
```

```
// map(f)(map(g)(y)) === map((x: X) => f(g(x)))(y)
```

Functor



Zip

```
zip: (F[X],F[Y]) => F[(X,Y)]
```

```
// map(_._1)(zip(fx, fy)) === fx
```

```
// map(_._2)(zip(fx, fy)) === fy
```

```
// zip(map(_._1)(z),map(_._2)(z)) === z
```

Unit

```
unit: X => F[X]  
  
// map(f)(unit(x)) == unit(f(x))
```

Traverse

```
traverse: (X => F[X]) => List[X] => F[List[X]]  
  
// traverse(f)(Nil) == unit(Nil)  
// traverse(f)(h :: t) == map{  
//   case (x,y) => x :: y  
// }(zip(f(h),traverse(f)(t)))
```


Applicative functor

```
map: (X => Y) => F[X] => F[Y]
zip: (F[X], F[Y]) => F[(X,Y)]
unit: X => F[X]
traverse: (X => F[X]) => List[X] => F[List[X]]
```

Bind

```
bind: (X => F[Y]) => F[X] => F[Y]

// bind(f)(bind(g)(x)) === bind((y: X) =>
    bind(f)(g(y))(x))
// bind(unit)(x) === x
// bind(f)(unit(x)) === unit(f(x))

// map(f)(x) === bind((y: X) => unit(f(y)))(x)
// zip(x,y) === bind((x0: X) => map((y0: Y) => (x0, y0)))
```

ReduceM

```
reduceM: F[X] => (X => X => F[X]) => List[X] => F[X]
```

```
// reduceM(a)(b)(Nil) === unit(a)
```

```
// reduceM(a)(b)(h :: t) === bind(b(h))(reduceM(a)(b)(t))
```

Monad

```
unit: X => F[X]  
bind: (X => F[Y]) => F[X] => F[Y]  
reduceM: F[X] => ((X,X) => F[X]) => List[X] => F[X]
```

scala.concurrent.Future

- ▶ used in calendars api, savings me api
- ▶ Scala standard library

Asynchronous interface

```
abstract class Cassandra(implicit ec:ExecutionContext) {  
  def prepare(statement: String):  
    Future[PreparedStatement]  
  def prepare(statement: RegularStatement):  
    Future[PreparedStatement]  
  def execute(statement: String): Future[Unit]  
  def execute(statement: BoundStatement): Future[Unit]  
}
```

- ▶ Future.successful and Future.apply for unit
- ▶ flatMap for bind
- ▶ Future.traverse exists

Continuation passing style

Continuation passing style

- ▶ abstracts over the notion of registering callbacks
- ▶ can mimic any monad
- ▶ reasonable solution in Java

Continuation passing style monad

```
object CPSMonad {  
  
  type CPS[X] = (X => Unit) => Unit  
  
  def unit[X](x: => X): CPS[X] = (c: X => Unit) => c(x)  
  
  def bind[X, Y](f: X => CPS[Y])(cx: CPS[X]): CPS[Y] =  
    (cy: Y => Unit) => cx((x: X) => f(x)(cy))  
  
  //...  
}
```


Stacksafe traverse

```
def traverse[X, Y](f: X => CPS[Y])(lx: List[X]):  
  CPS[List[Y]] = {  
    @tailrec def helper(lx: List[X], cy: List[Y] =>  
      Unit): Unit = lx match {  
      case Nil => cy(Nil)  
      case hx :: tx => helper(tx, (ty: List[Y]) =>  
        f(hx)((hy: Y) => cy(hy :: ty)))  
    }  
    helper(lx,_)  
  }
```

Free monads

- ▶ Reify everything
- ▶ Build and manipulate ASTs for later interpretation

Free monad constructors

```
sealed trait Free[F[_], X]

case class Return[F[_], X](x: X) extends Free[F, X]

case class Effect[F[_], X](fx: F[X]) extends Free[F, X]

case class Bind[F[_], X](f: X => Free[F, X], frx: Free[F, X]) extends Free[F, X]

case class Traverse[F[_], X](f: X => Free[F, X], lx: List[X]) extends Free[F, List[X]]
```

Effect constructors

```
sealed trait CassandraEffect[X]

case class PrepareString(statement: String) extends
  CassandraEffect[PreparedStatement]

case class PrepareRegular(statement: RegularStatement)
  extends CassandraEffect[PreparedStatement]

case class ExecuteString(statement: String) extends
  CassandraEffect[ResultSet]

case class ExecuteStatement(statement: Statement) extends
  CassandraEffect[ResultSet]
```

Generic monad

- ▶ abstract over monads themselves
- ▶ dependency injection applied to monads

Monad type class

```
trait Monad[M[_]] {  
  
  def unit[X] (x: X): M[X]  
  
  def bind[X, Y] (f: X => M[Y]) (mx: M[X]): M[Y]  
  
  def traverse[X, Y] (f: X => M[Y]) (lx: => List[X]):  
    M[List[X]]  
}
```

Generically wrapped interface

```
abstract class Cassandra[F: Monad] {  
  def prepare(statement: String): F[PreparedStatement]  
  def prepare(statement: RegularStatement):  
    F[PreparedStatement]  
  def execute(statement: String): F[Unit]  
  def execute(statement: Statement): F[Unit]  
}
```

Summary

- ▶ 'functor', 'applicative functor' and 'monad' specify interfaces that handle callbacks, in increasing power
- ▶ 'Future', 'continuation passing style', 'free monads' and 'generic monads' show a range of technical implementations that can hide behind those interfaces