Solving The Dependency Injection Problem With ZIO

Agenda

- **Introduction to ZIO**
- The Dependency Injection Problem
- ZIO's Environment Type
- Using Layers to Build Environments

Mental Model

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type ZIO[-R, +E, +A] = R => Either[E, A]
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- A `ZIO[R, E, A]` is a description of a computation that requires an environment `R` and may either fail with an error `E` or succeed with a value `A`
- A description of a potentially asynchronous computation
- You can think of `ZIO` as a future on steroids

Hello ZIO

```scala
object HelloZIO extends App {

  def run(args: List[String]): ZIO[ZEnv, Nothing, Int] =
    sayHello.as(0)

  val sayHello: ZIO[Console, Nothing, Unit] =
    console.putStrLn("Hello, ZIO!")
}
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Composable Descriptions

A ZIO is a description of a computation instead of a running computation so they are incredibly composable:

```
val dice: ZIO[Random, Nothing, Int] =
  random.nextInt(6).map(_ + 1)

val pair: ZIO[Random, Nothing, Int] =
  dice.zipWith(dice)(_ + _)

val sample: ZIO[Console with Random, Nothing, Unit] =
  ZIO.collectAll_ {
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Lossless Error Model

Polymorphic error type allows you to tell how your computations can fail, if they can fail at all:

```
sealed trait PasswordError
case object IOError         extends PasswordError
case object InvalidPassword extends PasswordError

val getInput: ZIO[Console, IOError, String] = ???

def validateInput(password: String): ZIO[Any, InvalidPassword, Password] = ???

val getAndValidateInput: ZIO[Console, PasswordError, Password] =
  getInput.flatMap(validateInput)

val getPassword: ZIO[Console, Nothing, Password] =
  getAndValidateInput.orElse(getPassword)
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Fiber Based Concurrency

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Fibers are lightweight equivalents of threads:

- Can have hundreds of thousands of fibers at a time
- Semantically block but never block underlying operating system thread
- Safely interruptible
- Automatic supervision

Parallelism

ZIO makes it simple to write safe parallel programs:

```
def decrypt(data: Array[Byte]): ZIO[Any, Nothing, String]     = ???
def validate(data: Array[Byte]): ZIO[Any, InvalidData, Unit] = ???

for {
  fiber  <- decrypt(data).fork
  _      <- validate(data)
  result <- fiber.join
} yield result
```

Concurrency

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- *Race* - the slower of two computations will be immediately interrupted
- *Bracket* - resource will always be released when computation is terminated
- *Lock* - computation will always be executed on specified executor

Safe Resource Usage

```
try {
    resource = acquire
    doSomething(resource)
} finally {
   resource.release
}
```

Try finally doesn't work with asynchronous or concurrent code

Composable Resources

```
val resource1 = ZManaged[Any, Nothing, A]
val resource2 = ZManaged[Any, Nothing, B]
val resource3 = ZManaged[Any, Nothing, C]

for {
  a      <- resource1
  (b, c) <- resource2.zipPar(resource3)
} yield f(a, b, c)
```

Resources are guaranteed to be acquired in correct order and released as soon as possible

Concurrent Data Structures

"Batteries included" library of concurrent data structures to solve any problem:

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- *Ref* - concurrent state
- *Promise* - single element coordination between fibers
- *Queue* - multiple element coordination between fibers
- *STM* - full software transactional memory library

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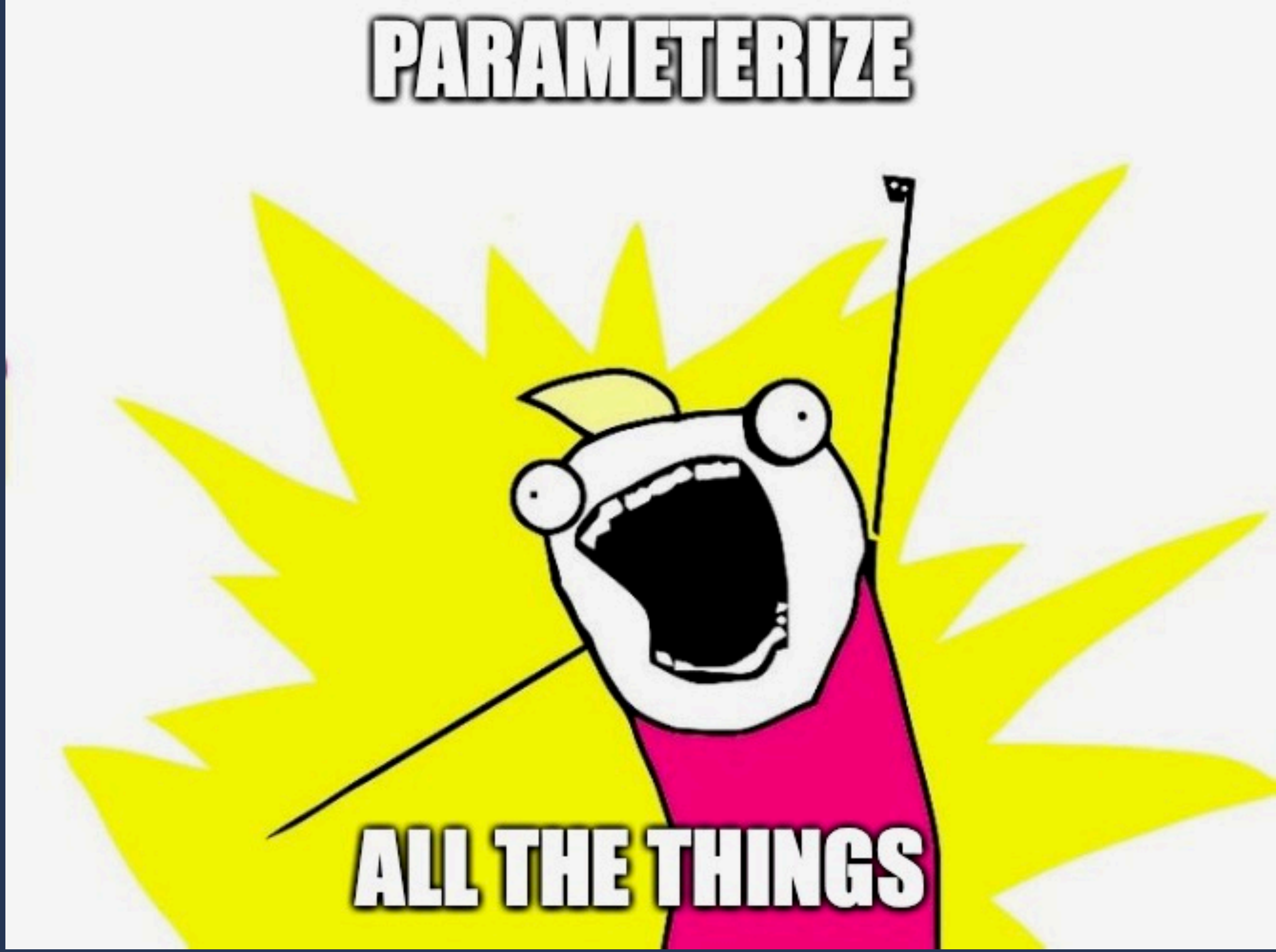
How Do We Get Dependencies To Where They Are Needed?

```scala
trait Bloomberg {
  def getStockPrice(ticker: String): Future[Double]
}

def executeTrades(bloomberg: Bloomberg): Unit =
  ???

// ten layers down...

def appleStockPrice: Future[Double] =
  bloomberg.getStockPrice("AAPL")
```

Traditional Solutions

1. Argument Passing
2. Implicit Parameters
3. Constructor Arguments
4. Cake Pattern
5. Specialized Frameworks

Argument Passing



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Problems:

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- Have to include in all calls to those functions
- Doesn't scale to many dependencies

Implicit Parameters

Just make them implicit:

```
def getStockPrices(
  tickers: List[String]
)(implicit bloomberg: Bloomberg): Future[List[Double]] =
  Future.traverse(tickers)(bloomberg.getStockPrice)
```

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Implicit Parameters

Problems:

- Have to include in all function definitions that directly or indirectly use dependency
- ~~Have to include in all calls to those functions~~
- Doesn't scale to many dependencies
- Harder to reason about and more error prone

Constructor Arguments

```
class StockTradingService(bloomberg: Bloomberg) {
  def getStockPrice(ticker: String): Future[Double] =
    bloomberg.getStockPrice(ticker)
  // more methods here
}
```

Problems

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- Allocation and deallocation of resources

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- Encourages use of dependency injection framework
- Hard to refactor

Cake Pattern

```scala
trait BloombergService {
  def getStockPrice(ticker: String): Future[Double]
}

trait Bloomberg {
  def bloomberg: BloombergService
}

object LiveBloomberg extends Bloomberg {
  ???
}

trait TradeExecution { self: Bloomberg =>
  val appleStockPrice = bloomberg.getStockPrice("AAPL")
}

object LiveTradeExecution extends TradeExecution with LiveBloomberg
```

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Specialized Frameworks

Use macros or reflection to dynamically inject dependencies:

- Guice
- Spring
- MacWire
- Airframe

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- "Magic" - when it works it works, otherwise good luck

Specialized Frameworks

Problems:

- Have to learn domain specific language
- "Magic" - when it works it works, otherwise good luck
- Lack of type safety

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- Allows us to describe our whole program and its dependencies, deferring providing their implementations until the "end of the world"

Mental Model

`ZIO[-R, +E, +A] = R => Either[E, A]`

- A `ZIO` computation can require an environment `R` to be run
- Allows us to describe our whole program and its dependencies, deferring providing their implementations until the "end of the world"
- Computations that don't require any environment have `R` of `Any`

Accessing the Environment

Access the environment using `ZIO.environment`:

```
def getStockPrice(ticker: String): ZIO[Bloomberg, BloombergError, Double] =
  ZIO.environment[Bloomberg].flatMap(_.getStockPrice(ticker))
```

A computation that requires a Bloomberg service and either succeeds with a stock price or fails with a domain specific error

Providing the Environment

Provide the environment using `ZIO#provide`:

```
val appleStockPrice: ZIO[Any, BloombergError, Double] =
  getStockPrice("AAPL").provide(Bloomberg.Live)
```

A computation that has been provided with its required environment and is ready to be run

Environmental Requirements Compose

Combining two computations requires both of their environments:

```
def getStockPrice(ticker: Ticker): ZIO[Bloomberg, BloombergError, Double]        = ???
def logPrice(ticker: String, price: Double): ZIO[Logging, Nothing, Unit] = ???

def getAndLogPrice(ticker: String): ZIO[Bloomberg with Logging, BloombergError, Double] =
  for {
    price <- getStockPrice(ticker)
    _     <- logPrice(ticker, price)
  } yield price
```

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```

Environmental Requirements Scale

```scala
type Trading = Bloomberg with Logging

def getAndLogPrice(ticker: String): ZIO[Trading, BloombergError, Double] =
  ???
```

We can use `with` to concisely describe complex environments

Pain Points

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While a giant step forward, there have been some limitations in working with environment in previous ZIO versions:

- boilerplate in constructing environments
- difficulty locally modifying and eliminating environments

Boilerplate in Constructing Environments

```
trait Bloomberg {
  def bloomberg: Bloomberg.Service
}

object Blooberg {
  trait Service {
    def getStockPrice(ticker: String): IO[BloombergError, Double]
  }
}

trait Logging {
  def logging: Logging.Service
}

object Logging {
  trait Service {
    def logLine(line: String): UIO[Unit]
  }
}
```

Boilerplate in Constructing Environments

```
val appleStockPrice: ZIO[Bloomberg, BloombergError, Double] =
  getAndLogPrice("AAPL").provideSome[Bloomberg] { env =>
    new Bloomberg with Logging {
      val bloomberg = env.bloomberg
      val logging = Logging.Live.logging
    }
  }
```

Difficulty Locally Modifying and Eliminating Environments

```
def modifyClock[R <: Clock, E, A](
  zio: ZIO[R, E, A]
)(f: Clock.Service => Clock.Service): ZIO[R, E, A] =
  zio.provideSome[R] { r =>
    ???
  }
```

The Mix Problem

```
def mix[A, B](a: A, b: B): A with B =
  ???
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- Previous solutions, including the `Mix` type class from the ZIO Macros project and the `Enrich` type class from Netflix's Polynote project have used macros to solve this problem
- Not ideal experience for a core library feature

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Has

```
Has[A] with Has[B] with Has[C]
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`Has[A] with Has[B] with Has[C]`

- Backed by heterogenous map from types to values

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`Has[A] with Has[B] with Has[C]`

- Backed by heterogenous map from types to values
- We know how to build and combine maps, we don't know how to build and combine abstract types

Heterogenous Map

```
Has[Blocking.Service] with Has[Random.Service]
  with Has[Clock.Service] with Has[Console.Service]
  with Has[System.Service]

Map(
  Tagged[Blocking.Service] -> BlockingServiceLive,
  Tagged[Random.Service]   -> RandomServiceLive,
  Tagged[Clock.Service]    -> ClockServiceLive,
  Tagged[Console.Service]  -> ConsoleServiceLive,
  Tagged[System.Service]   -> SystemServiceLive
)
```

Defining Services

```
type Bloomberg = Has[Bloomberg.Service]
type Logging   = Has[Logging.Service]

object Bloomberg {
  trait Service {
    def getStockPrice(ticker: String): IO[BloombergError, Double]
  }
}

object Logging {
  trait Service {
    def logLine(line: String): UIO[Unit]
  }
}
```

ZLayer

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ZLayer[-RIn, +E, +ROut <: Has[_]]
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ZLayer

`ZLayer[-RIn, +E, +ROut <: Has[_]]`

- A `ZLayer[RIn, E, ROut]` is a "recipe" for building an environment of type `ROut`
- Layers can require allocation and deallocation
- Layers are shared by default, so if the same layer is used in multiple parts of your dependency graph it will only be created once

Layers Compose

Layers compose horizontally and vertically:

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Layers compose horizontally and vertically:

- *Horizontally* - Combine two layers with ++ to get a new layer that requires both of their inputs and produces both their outputs
- *Vertically* - Combine one layer that depends on another with >>> to get a new layer that takes the input to the first and produces the output of the second

Horizontal Composition

```
object ZEnv {
  val live: ZLayer[Any, Nothing, Clock with Console with Random with System] =
    Clock.live ++ Console.live ++ Random.live ++ System.live
}
```

Vertical Composition

```
object TestEnvironment {
  val live =
    Annotations.live ++
      (Live.default >>> TestClock.default) ++
      TestConsole.default ++
      Live.default ++
      TestRandom.random ++
      Sized.live(100) ++
      TestSystem.default
}
```

Layers Can Require Finalization

```
val bloombergLayer: ZLayer[Any, Nothing, Bloomberg] =
  ZLayer.fromManaged {
    Managed.make(
      acquireBloombergService,
      releaseBloombergService
    )
  }
```

Locally Eliminating Dependencies

```
val getAndLogPrice: ZIO[Bloomberg with Logging, BloombergError, Double] =
  ???

val liveLogging: ZLayer[Any, Nothing, Logging] = ???

val appleStockPrice: ZIO[Bloomberg, BloombergError, Double] =
  getAndLogPrice.provideSomeLayer[Bloomberg](liveLogging)
```

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Locally Updating Dependencies

Easy to locally update services:

```
val tradingLayer: ZLayer[Any, Nothing, Bloomberg with WorldBank with Logging] =
  ???

val updated = tradingLayer.updated[Logging] { loggingService =>
  // update logging service to display in black and white
  ???
}
```

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Locally Overriding Dependencies

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Impossible to Create Cyclic Dependencies

```
lazy val chickenLayer: ZLayer[Egg, Nothing, Chicken] = ???
lazy val eggLayer: ZLayer[Chicken, Nothing, Egg]     = ???

lazy val circular: ZLayer[Chicken, Nothing, Egg] =
  eggLayer >>> chickenLayer >>> eggLayer
```

Impossible to Create Cyclic Dependencies

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lazy val circular: ZLayer[Chicken, Nothing, Egg] =
  eggLayer >>> chickenLayer >>> eggLayer
```

Benefits Of ZLayer

- Powerful
- Concise and ergonomic
- Type safe
- Resource safe
- No "magic"

Conclusion

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- ZIO's environment type provides a comprehensive solution to the dependency injection problem
- Try it out and visit us on Github and Discord

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- All of you for taking time out of your day to attend