dist✪ge

Modern Staged Dependency Injection for Scala

Modular Functional Programming
with
Context Minimization
through
Garbage Collection

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The motivation behind DI pattern and DI frameworks

1. Systems we work with may be represented as graphs. Nodes are components (usually instances), edges are references,
2. Graph transformation complexity grows non-linearly with nodes count (need to add one constructor parameter, have to modify k classes),
3. Graph composition has combinatoric complexity (need to run tests choosing between mock/production repositories and external APIs, have to write four configurations).

We have several possible options to address these problems:

1. Singletons and Factories: solves tight coupling but expensive tests and refactorings,
2. Service Locator: bit less coupling but still expensive,
3. Dependency Injection: less invasive and supports isolation but requires more complex machinery.

"DI doesn't compose with FP": Problems

1. Typical DI framework is OOP oriented and does not support advanced concepts required for modern FP (typeclasses, higher-kinded types),
2. Almost all the DI frameworks are working in runtime while many modern FP concepts are compile-time by their nature,
3. Less guarantees: program which compiles correctly can break on wiring in runtime. After a huge delay,
4. Wiring is non-determenistic: Guice can spend several minutes trying to re-instantiate heavy instance multiple times (once per dependency) then fail,
5. Wiring is opaque: it's hard or impossible to introspect the context. E.g. in Guice it's a real pain to close all the instantiated `Closeables`. Adding missing values into the context (config injections) is not trivial as well.

"DI doesn't compose with FP": Notes

1. We have some compile-time DI frameworks or mechanisms (see `MacWire`) allowing us to implement DI as pattern though purely compile-time tools are not convenient when we have to deal with purely runtime entities (like plugins and config values),
2. Graph composition problem is not addressed by any existing tool.

DI implementations are broken…

…so we may build better one, which must:

1. be well-integrated with type system of our target language (higher-kinded types, implicits, typeclasses),
2. allow us to introspect and modify our context on the fly,
3. be able to detect as many as possible problems quickly, better during compilation,
4. give us a way to stop making atomic or conditional contexts.

Staged approach

1. Let's apply *Late Binding*,
2. let's collect our graph information first,
3. then build a DAG representing our context (so-called *Project Network*, let's call it *Plan*),
4. then analyse this graph for errors (missing references, conflicts),
5. then apply additional transformations,
6. then interpret the graph.

This is a cornercase of more generic pattern – PPER (Percept, Plan, Execute, Repeat).

Staged approach: outcome

What we get:

1. Planner is *pure*: it has no side-effects,
2. A plan is a Turing-incomplete program for a simple machine. It will always terminate in known finite time,
3. An interpreter may perform instantiations at runtime or...just generate Scala code that will do that when compiled,
4. All the job except of instantiations can be done in compile-time,
5. Interpreter is free to run independent instantiations in parallel,
6. Extremely important: we can transform (rewrite) the plan before we run iterpreter.

Compile-Time and Runtime DI

A Plan:

```
myRepository := create[MyRepository]()
myservice    := create[MyService](myRepository)
```

May be interpreted as:

Code tree (runtime):

```scala
val myRepository =
    new MyRepository()
val myservice =
    new MyService(myRepository)
```

Set of instances (runtime):

```scala
plan.foldLeft(Context.empty) {
case (ctx, op) =>
    ctx.withInstance(
        op.key
        , interpret(action)
    )
}
```

Incomplete plans

This code:

```scala
class UsersRepoImpl(cassandraCluster: Cluster)
    extends UsersRepo
class UsersService(repository: UsersRepo)

class UsersModule extends ModuleDef {
  make[UsersRepo].from[UsersRepoImpl]
  make[UsersService]
}
```

May produce a plan like:

```
cassandraCluster      := import[Cluster]
usersRepo: UsersRepo  := create[UsersRepoImpl](cassandraCluster)
usersService          := create[UsersService](usersRepo)
```

Pattern: Plan completion

Once we have such a plan:

```
cassandraCluster      := import[Cluster]
usersRepo: UsersRepo := create[UsersRepoImpl](cassandraCluster)
usersService          := create[UsersService](usersRepo)
```

We may add missing values[1]:

```
val plan = Injector.plan(definitions)
val resolved = plan.map {
  case i: Import if i.is[Cluster] =>
    val cluster: Cluster = ???
    Reference(cluster)
  case op => op
}
```

[1] Pseudocode, real API is bit different

Extension: Configuration Support

distage has HOCON configuration support implemented as an extension.

```scala
case class HostPort(host: String, port: Int)

class HttpServer(@ConfPath("http.listen") listenOn: HostPort) {
  // ...
}
```

The extension:

1. Takes all the Imports of a Plan,
2. Searches them for a specific @ConfPath annotation,
3. Tries to find corresponding sections in config,
4. Extends plan with config values,

All the config values are resolved even before the services being instantiated ⇒ problems are being shown quickly and all at once.

Extension: Automatic Sets

1. distage can find all instances type `T` (like `AutoCloseable`) in the context, put them all into a `Set[T]` then inject that set.
2. ⇒ basic lifecycle support, free of charge.

```scala
trait Resource {
  def start(): Unit
  def stop(): Unit
}
trait App { def main(): Unit }
locator.run { (resources: Set[Resource], app: App) =>
  try {
    resources.foreach(_.start())
    app.main()
  } finally {
    resources.foreach(_.close())
  }
}
```

The Principle Behind: PPER Loop

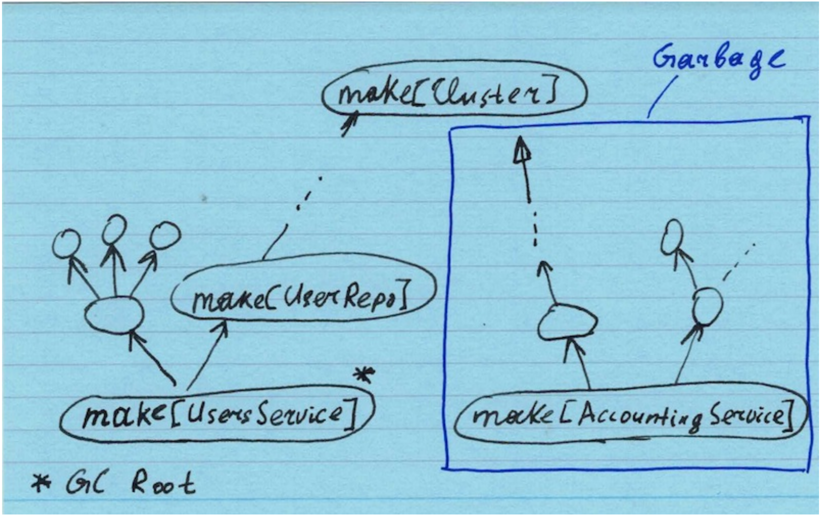
A very generic and a very important pattern:

1. Acquire data from the outer world (*Percept*)
2. Produce a Project Network, *Plan*. It may be incomplete, but should allow us to progress (*Plan*)
    - Plan is a DAG where actions are nodes and edges are dependencies
3. Execute the Plan (*Execute*).
    - Perform the steps of the Plan
    - Mark your Plan nodes according to the results of their execution
    - Let's call marked plan as *Trace*
4. Go to step 1 unless termination criteria reached (*Repeat*)

Garbage Collector and Context Minimization

1. Let's assume that we have a `UsersService` and `AccountingService` in your context,
2. ...and we want to write a test for `UsersService` only,
3. We may exploit staged design and *collect the garbage* out of Plan before executing it.
4. We define a *garbage collection root*, `UsersService`, and keep only the operations it transitively depends on. The rest is being thrown out **even before it's being instantiated**,
5. Garbage Collector allows us to compose contexts easier.

Garbage Collector and Context Minimization



Context Minimization for Tests

Context minimization allows us to:

1. Instantiate only the instances which are required for your tests,
2. Save on test startup time (savings may be significant),
3. Save on configuring per-test contexts manually (savings may be substantial).

Context Minimization for Deployment

Context minimization allows us to:

1. Have one image with all our software components (*Roles*[1]),
2. . . . keeping development flows of these components isolated,
3. Decide which components we want to run when we start the image,
4. Have higher computational density
5. *substantially* simplify development flows: we may run full environment with a single command on a low-end machine,
6. Fuse Microservices with Monoliths keeping *all* their benefits.

```
server1# docker run -ti company/product +analytics
server2# docker run -ti company/product +accounting +users
laptop# docker run -ti company/product --run-everything
```

[1] Presentation: https://goo.gl/iaMt43

Kind-Polymorphic Type Tags

1.

Typeclass instance injection (Implicit Injection)

1.

Lambda injection and Parameter Magnet

1.

Code example: IO Injection

1.

Code example: Tagless Final Style

1.

Dynamic Plugins

1.

Tags

1.

Plan Introspection

1.

Trait Completion

1. Runtime and Compile-time.

Factory Methods (Assisted Injection)

1. Useful for Akka, lot more convenient than Guice,
2. Runtime and Compile-time.

Status and things to do

`distage` is:

1. ready to use,
2. in real production,
3. all Runtime APIs are available,
4. Compile-time verification, trait completion, assisted injections and lambda injections are available.

Our plans:

1. Refactor Roles API,
2. Support running Producer within a monad (IO),
3. Support Scala.js,
4. Support optional isolated classloaders (in foreseeable future),
5. Publish compile-time Producer,
6. Check our GitHub: https://github.com/pshirshov/izumi-r2.

distage is just a part of our stack

We have a vision backed by our tools:

1. Idealingua: transport and codec agnostic gRPC alternative with rich modeling language,
2. LogStage: zero-cost logging framework,
3. *Fusional Programming and Design* guidelines. We love both FP and OOP,
4. *Continous Delivery* guidelines for Role-based process,
5. *Percept-Plan-Execute* Generative Programming approach, abstract machine and computational model. Addresses Project Planning (see Operations Research). Examples: orchestration, build systems.

Altogether these things already allowed us to significantly reduce development costs and delivery time for our client.

More slides to follow.

Teaser: LogStage

Teaser: Idealingua

Thank you for your attention

https://izumi.7mind.io/

We're looking for clients, contributors, adopters and colleagues ;)

About the author:

1. coding for 18 years, 10 years of hands-on commercial engineering experience,
2. has been leading a cluster orchestration team in Yandex, "the Russian Google",
3. implemented "*Interstellar Spaceship*" – an orchestration solution to manage 50K+ physical machines across 6 datacenters,
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