Datatype Generic Programming with Scala 3

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https://github.com/y-yu/scalamatsuri2023 (f036ba9)

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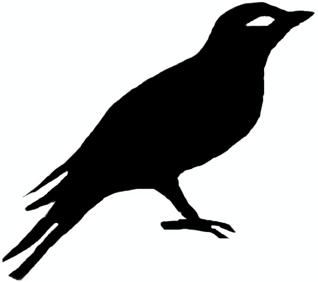
Who am I?



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`TestObject`: generating fixtures for unit tests

- We uses `TestObject` on our product, which is a utility to generate dummy objects(as known as *fixtures*) for unit tests.

```scala
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- Type class `TestObject[A]` provides us to the way for generating some value of `A`.

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trait TestObject[A] {
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implicit val strInstance: TestObject[String] = new TestObject {
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- In naive way, we have to define too many `TestObject` implicit instances for every types used in our product, but it's not possible and reasonable.

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- The many `TestObject` instances can be provided by *datatype generic programming*, not manually.
  - We can get `dummyData: StudySapuriSession` easily once we define `TestObject` instances for primitive or Java types,
  - Then datatype generic programming generates the other instances for our defined data structures(= case objects).

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  - Then datatype generic programming generates the other instances for our defined data structures(= case objects).
- Datatype generic programming is the one of the ways of meta-programming.
- In this talk I'll explain datatype generic programming with Scala 3.

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- Almost every data structure can be classified either "tuple" like or "enum" like:

```scala
case class TupleLike(
  field1: Int, field2: String
)
```

```scala
sealed trait EnumLike
case class Pattern1(v: Int)    extends EnumLike
case class Pattern2(v: String) extends EnumLike
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  - `TupleLike` requires both two values of `Int` and `String`, on the other hand `EnumLike` requires either `Int` value or `String` value.

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  - `TupleLike` requires both two values of `Int` and `String`, on the other hand `EnumLike` requires either `Int` value or `String` value.
- Datatype generic programming provides us following two functions: ❶ converting a type value to the analogy tuple or enum and ❷ reverting it to the original type.

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  2. Then find some implicit instances based on the types included in the tuple or enum.
  3. Finally revert the derived instance for tuple or enum like to one for the original data type.

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  2. Then find some implicit instances based on the types included in the tuple or enum.
  3. Finally revert the derived instance for tuple or enum like to one for the original data type.
- `case class TupleLike(field1: Int, field2: String)` example:

$$\dfrac{\texttt{TupleLike} \Leftrightarrow \texttt{(Int, String)} \qquad \dfrac{\texttt{TestObject[Int]} \qquad \texttt{TestObject[String]}}{\texttt{TestObject[(Int, String)]}}\;\text{②}}{\texttt{TestObject[TupleLike]}}\;\text{①}$$

where `TupleLike` $\Leftrightarrow$ `(Int, String)` is powered by datatype generic programming.

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- Likewise on our product, we are compiling & testing both of Scala 2 and 3 for almost all code.
- There is no compatibility of macros between Scala 2 and 3 😇
- It follows that `TestObject` implemented on Scala 2 won't work well on Scala 3.
    - *shapeless 3*[2] for Scala 3 is being developed but unfortunately it doesn't have compatibility of shapeless for Scala 2 😇

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- Likewise on our product, we are compiling & testing both of Scala 2 and 3 for almost all code.
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- It follows that `TestObject` implemented on Scala 2 won't work well on Scala 3.
    - *shapeless 3*[2] for Scala 3 is being developed but unfortunately it doesn't have compatibility of shapeless for Scala 2 😇
- Eventually we(mainly ScalaNinja) began to develop another `TestObject` implementation for Scala 3

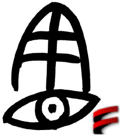

Fig 1: ScalaNinja

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```scala
import scala.compiletime.*
import scala.deriving.*
case class TupleLike(
  field1: Int, field2: String
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```

```scala
scala> Tuple.fromProductTyped(TupleLike(1, "a"))
val res0: (Int, String) = (1,a)

scala> summon[Mirror.ProductOf[TupleLike]].fromProduct(res0)
val res1: TupleLike = TupleLike(1,a)
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- We can use some functions to convert case objects from/to tuple like without any libraries.
- Meta-programming tools in Scala 3 is reinforced rather than Scala 2 👍

`TestObject` implementation on Scala 3

- We'll define `derive` method as the final goal such like:

```scala
inline implicit def derive[A]: TestObject[A]
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  - `derive` provides `TestObject` instances for all `A`.

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- This is the overview of `derive` behavior:
  1. Check if the instance for the input type has been defined.
  2. If not found, pattern match the type into either tuple like or enum like.
  3. Collect the *ill-typed* list of `TestObject` for each types contained in 2 using `erasedValue`.
  4. Finally make the instance for the input type using 3 instances list.

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- Let's see the details!

❶ Check if the instance for the input type has been defined

- `summonFrom` searches the `TestObject` instance for type `A`.

```
inline implicit def derive[A]: TestObject[A] =
  summonFrom {
    case x: TestObject[A] =>
      x
    case _ =>
      create[A] // we'll define next page!
  }
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Fig 2: Image of `summonFrom`

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- If `summonFrom` finds the `TestObject[A]` instance, then the instance would be named as `x`.
  - In this case, it's unnecessary to define the instance so returns `x`.
- In the latter case, we call `create` method to define `TestObject[A]`.

❷ Pattern matching if `ProductOf[A]` or `SumOf[A]`

- Since there is no `TestInstance[A]` instance yet, `create` finds `ProductOf[A]` or `SumOf[A]` instance using `summonFrom` again.

```
inline final def create[A]: TestObject[A] =
  summonFrom {
    case _: Mirror.ProductOf[A] =>
      deriveProduct[A] // 1
    case _: Mirror.SumOf[A] =>
      deriveSum[A]     // 2
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```

- It means that:
  1. `A` is a tuple like type (i.e. case classes) if there is a `ProductOf[A]` instance,
  2. `A` is an enum like structure (i.e. sealed traits). if there is a `SumOf[A]` instance.

❸ Make *ill-typed* instances list: `List[TestObject[?]]`

- Before see `deriveProduct` and `deriveSum`, we have to prepare the way to collect all instances for types being contained in `A`.
  - For example `TupleLike`, we need the both instances of `TestObject[Int]` and `TestObject[String]`.

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- `erasedValue` allows us to search and collect all instances recursively.

```
inline def deriveRec[T <: Tuple]: List[TestObject[?]] =
  inline erasedValue[T] match {
    case _: EmptyTuple =>
      Nil
    case _: (t *: ts) =>
      derive[t]/* mutual recursion */ :: deriveRec[ts]
  }
```

- There is no type compatibility among the instances, `deriveRec` cannot help but to return *ill-typed* list 😇

❸ Make *ill-typed* instances list: `List[TestObject[?]]`

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- There is no type compatibility among the instances, `deriveRec` cannot help but to return *ill-typed* list 😇

- In addition `*:` is type-level tuple constructor provided since Scala 3.

4a In `deriveProduct` case

- Using `deriveRec`, we define `TestObject` instance for `A` in `deriveProduct` case.

```
inline def deriveProduct[A](using a: ProductOf[A]): TestObject[A] = {
  def p: TestObject[A] = {
    val xs = deriveRec[a.MirroredElemTypes] // `a.MirroredElemTypes` is analogy tuple of `A`.
    productImpl[A](xs, a)
  }
  p
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```

  - Why does `deriveProduct` only call `productImpl` through temporary method `p`?🤔

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- This is ScalaNinja's remarkable and state-of-the-art technique to avoid
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  - and generating too many nameless classes.

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- This is ScalaNinja's remarkable and state-of-the-art technique to avoid
  - throwing `MethodTooLargeException` due to `inline`
  - and generating too many nameless classes.
- In meta-programming, we have to consider about compiling efficiency, not only runtime. That's maybe the why meta-programming is difficult 😇

4a In `deriveProduct` case

- First we make `values` which are all values required by `A`.

```scala
final def productImpl[A](xs: List[TestObject[?]], a: ProductOf[A]): TestObject[A] =
  new TestObject[A] {
    def generate: IntState[A] =
      for {
        values <- xs.traverse(_.generate.widen[Any])
      } yield a.fromProduct(new SeqProduct(values))
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  - It's important that `productImpl` doesn't have `inline`.
- Then making `A` value using `a.fromProduct`.

4b In `deriveSum` case

- In `SumOf` case, we generate a value in `values`.

```
inline def deriveSum[A](using a: SumOf[A]): TestObject[A] = {
  def s: TestObject[A] = {
    val values = deriveRec[a.MirroredElemTypes]
    sumImpl[A](values)
  }
  s
}
```

- It's very similar to `deriveProduct`.

4b In `deriveSum` case

- `sumImpl` is very complicated 😇

```
final def sumImpl[A](values: List[TestObject[?]]): TestObject[A] =
  new TestObject[A] {
    def generate: IntState[A] =
      for {
        allResults <- values.traverse(_.generate.widen[Any])
        l = allResults.minBy(_.getClass.getName)
        rOpt = allResults.tail.headOption.flatMap(
          _ => allResults.maxByOption(_.getClass.getName)
        )
        s <- State.get
      } yield rOpt match {
        case Some(r) => if (s % 2 == 0) l.asInstanceOf[A] else r.asInstanceOf[A]
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- What's the purpose of `minBy(_.getClass.getName)` and `maxByOption(_.getClass.getName)`?

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- For instance:

```
sealed trait X
case object X3 extends X
case object X2 extends X
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- shapeless 2 returns `X1 :+: X2 :+: X3`, which is sorted by alphabetical order,
- but `MirroredElemTypes` is `X3 *: X2 *: X1`😇

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  - but `MirroredElemTypes` is `X3 *: X2 *: X1`😇

- So the `minBy` and `maxByOption` is needed for the compatibility of shapeless 2 behavior.

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  - `https://github.com/y-yu/test-object`
  - It's maybe useful as proof-of-concept to compare Scala 2(shapeless 2) with Scala 3.

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  - Is there some ways how not using ill-typed list?🤔

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- There is no macro compatibility between Scala 3 and Scala 2 😇
  - And shapeless 2 and 3 don't have the same interface.
- Scala 3 supports datatype generic programming initially.
  - Is there some ways how not using ill-typed list?🤔
- Happy datatype generic programming!

- The number of lines of Scala 2 & 3 source code is 878,434 on March 1st.
    - It's not included generated code (for example protobuf & gRPC) so totally over 1,000,000 approximately.
- There are many micro services (Fig.3) and it's very complicated 😇
- The number of our server side team members is about 16.
- It's very useful for us to use meta-programming which is not only datatype generic programming but also *scalafix* and so on.

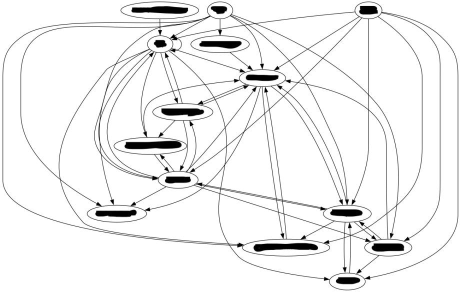

Fig 3: Very complicated micro services

References

[1] shapeless: generic programming for Scala (GitHub). `https://github.com/milessabin/shapeless`. Accessed: 2023-03-13.

[2] shapeless 3 for Scala 3 (GitHub). `https://github.com/typelevel/shapeless-3`. Accessed: 2023-03-13.

[3] shapeless 2 sorts subclasses by alphabetical order. `https://github.com/milessabin/shapeless/blob/da31eced505d3df9637a3a28825ff31c65a99ffe/core/shared/src/main/scala/shapeless/generic.scala#L412`. Accessed: 2023-03-13.

Thank you for the attention!