Your Scala code on steroids with Type Classes

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Learning new stuff...

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- Scala
  - Odersky et al's MOOCs
  - Twitter Scala School
- Haskell
  - Learn You a Haskell for Great Good! (LYaHfGG)
  - Haskell Wikibook

Basic Object-Oriented Programming

- Encapsulation
- Inheritance
- Polymorphism

...And some little problems...

Joe Armstrong (Erlang):

"The problem with object-oriented languages is they've got all this implicit environment that they carry around with them. You wanted a banana but what you got was a gorilla holding the banana and the entire jungle"!

Polymorphism VS. Inheritance

- Polymorphism lets you call methods of a class without knowing the exact type of the class
- Inheritance lets derived classes share interfaces and code of their base classes

Polymorphism

- Subtype polymorphism
    - Notion of substitutability
    - OOP: polymorphism using inheritance
- Parametric polymorphism
    - Java / Scala: with generics
- Ad-hoc polymorphism
    - Haskell / Scala: with type classes, F-bounded polymorphism (explicitly in Scala)

Some type classes pros

- Everything resolved at compile-time
- Type safety
- Plenty of room for compiler optimizations
- A form of retroactive supertyping that avoids structural types (their implementation needs reflection)
- Cleaner and more straight-forward code

Some type classes cons

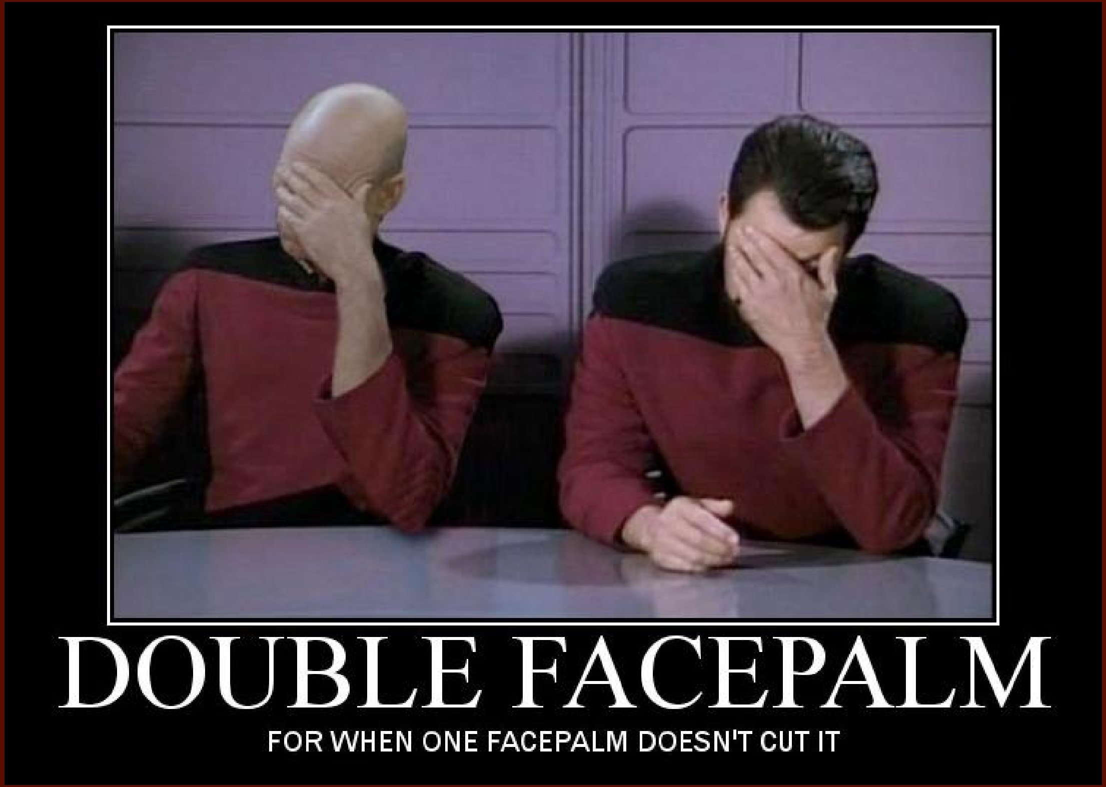
- Closer to the FP paradigm than the OOP counterpart (although FP and OOP are orthogonal)

    "Everything is an object"???

    Must read: https://wiki.haskell.org/OOP_vs_type_classes

- "Traditional programmers" are not familiar with them
- In Scala: implicits all over the place!
- In Scala: chains of type classes are tricky!

A trivial example



A trivial example

- We want to express approximate equality for a given type
- Approximate equality for numbers

  A number is approximately equal to another number iff the former is in a specified range of the latter
- The code is located at:

  https://github.com/dgk42/ScalaTypeClassesExample

Examples for range == 0.001

42 ~= 42 is true |*42 - 42*| == *0 < 0.001*

42 ~= 69105 is false |*42 - 69105*| == *69063 > 0.001*

5.01 ~= 5.02 is false |*5.01 - 5.02*| == *0.01 > 0.001*

5.00005 ~= 5.0008 is true

|*5.00005 - 5.0008*| == *0.00075 < 0.001*

5.1 + 2.8j ~= 5.1001 + 2.805j is false

sqrt((5.1 - 5.1001)^2 + (2.8 - 2.805)^2) ~= 0.005 > 0.001

Without type classes

```
trait WithDistanceG[T] {
  def v: T
  def distance(that: T): Double
}

trait ApproxEqualG[T] extends WithDistanceG[T] {
  def approxEqual(that: ApproxEqualG[T]): Boolean = distance(that.v) < 0.001

  def =~= = approxEqual(_)
  def =#= = { that: ApproxEqualG[T] =>
      !approxEqual(that)
  }
}
```

With type classes

```
trait WithDistanceTC[T] {
  def distance(t1: T, t2: T): Double
}

trait ApproxEqualTC[T] {
  def approxEqual(t1: T, t2: T)(implicit ev: WithDistanceTC[T]): Boolean =
      (ev distance (t1, t2)) < 0.001
}
```

With type classes (cont'd)

```
trait ApproxEqualTCSyntax[T] {
  def =~=(t: T): Boolean
  def =#=(t: T): Boolean
}

object ApproxEqualTCSyntax {
  implicit def approxEqualTCSyntax[T](t1: T)(
     implicit ev1: WithDistanceTC[T], ev2: ApproxEqualTC[T]): ApproxEqualTCSyntax[T] = {

     new ApproxEqualTCSyntax[T] {
       def =~=(t2: T): Boolean = ev2 approxEqual (t1, t2)
       def =#=(t2: T): Boolean = !(t1 =~= t2)
     }
  }
}
```

Let's implement approx. equality for Ints

Without type classes

```
class IntApproxEqualG(val v: Int) extends ApproxEqualG[Int] {
  def distance(that: Int): Double = math.abs(v - that).toDouble
}
```

With type classes

```
object IntWithDistanceTC {
  implicit val intHasDistance = new WithDistanceTC[Int] {
     def distance(t1: Int, t2: Int): Double = math.abs(t1 - t2).toDouble
  }
}

object IntApproxEqualTC {
  implicit val intIsApproxEqual = new ApproxEqualTC[Int] {}
}

// reference: trait ApproxEqualTC[T] {
//    def approxEqual(t1: T, t2: T)(implicit ev: WithDistanceTC[T]): Boolean =
//    (ev distance (t1, t2)) < 0.001
// }
```

Usage example

Without type classes

```
object GExample extends App {
  val t11 = new IntApproxEqualG(42)
  val t12 = new IntApproxEqualG(42)
  println(t11 =~= t12)
}
```

With type classes

```
object TCExample extends App {
  import IntWithDistanceTC._
  import IntApproxEqualTC._
  import ApproxEqualTCSyntax._

  println(42 =~= 42)
}
```

Notice that with type classes

- We operate on the `Int` type directly (we don't need a wrapper class)
- We don't need a `WithDistanceTC` implementation (although we provide one).
  This will eventually be provided at the call site (that is, `TCExample` in our case)

Notice that with type classes

- `IntWithDistanceTC`: We employ a form closer to the FP paradigm (distance with 2 arguments - compare with `IntApproxEqualG`)
- The singleton objects hold the implicit values. We don't spawn new objects all the time

Let's repeat this for a class of our own

```
// A trivial 2D vector implementation.
case class Vec2D(x: Double, y: Double) {
  def euclideanDistance(that: Vec2D): Double = {
     val dX = x - that.x
     val dY = y - that.y
     math.sqrt(dX * dX + dY * dY)
  }
```

Let's repeat this for a class of our own (cont’d)

```
  def manhattanDistance(that: Vec2D): Double = {
     val dX = math.abs(x - that.x)
     val dY = math.abs(y - that.y)
     dX + dY
  }
}
```

Important

We want to be able to choose the distance metric that will be used for the approximate equality attribute at the call site.

Important

Without type classes

```
class Vec2D1ApproxEqualG(val v: Vec2D) extends ApproxEqualG[Vec2D] {
  def distance(that: Vec2D): Double = v euclideanDistance that
}

class Vec2D2ApproxEqualG(val v: Vec2D) extends ApproxEqualG[Vec2D] {
  def distance(that: Vec2D): Double = v manhattanDistance that
}
```

With type classes

```
object Vec2DWithDistanceTC {
  implicit val vec2DHasDistance = new WithDistanceTC[Vec2D] {
     def distance(t1: Vec2D, t2: Vec2D): Double = t1 euclideanDistance t2
  }
}

object AnotherVec2DWithDistanceTC {
  implicit val anotherVec2DHasDistance = new WithDistanceTC[Vec2D] {
     def distance(t1: Vec2D, t2: Vec2D): Double = t1 manhattanDistance t2
  }
}
```

With type classes (cont’d)

```
object Vec2DApproxEqualTC {
  implicit val vec2DIsApproxEqual = new ApproxEqualTC[Vec2D] {}
}

// reference: trait ApproxEqualTC[T] {
//   def approxEqual(t1: T, t2: T)(implicit ev: WithDistanceTC[T]): Boolean =
//    (ev distance (t1, t2)) < 0.001
// }
```

With type classes

Notice that the `Vec2DApproxEqualTC`'s implicit val doesn't know anything about any distance metric.

Conclusion

- A natural way of expressing properties in domain entities
- "Pimp my lib" pattern
- Superior pattern to F-bounded polymorphism
- Scalaz is full of these!
- We love Haskell <=> We love Scalaz

BONUS STAGE

BONUS STAGE

Property testing with ScalaCheck and ScalaTest

BONUS STAGE

```
trait ApproxEqualTCLaws[T] {
  implicit val ev1: WithDistanceTC[T]
  implicit val ev2: ApproxEqualTC[T]

  def commutative(t1: T, t2: T): Boolean =
     (ev2 approxEqual (t1, t2)) == (ev2 approxEqual (t2, t1))
  def reflexive(t: T): Boolean = ev2 approxEqual (t, t)
  def transitive(t1: T, t2: T, t3: T): Boolean =
     conditional(
     (ev2 approxEqual (t1, t2)) && (ev2 approxEqual (t2, t3)),
     (ev2 approxEqual (t1, t3)))
}
```

BONUS STAGE

```
object ApproxEqualTCLawProperties {
  def approxEqualLaw[T](implicit e1: WithDistanceTC[T], e2: ApproxEqualTC[T]) =
     new ApproxEqualTCLaws[T] {
       val ev1 = e1
       val ev2 = e2
     }
```

BONUS STAGE

```
def commutativity[T](
    implicit ev1: WithDistanceTC[T], ev2: ApproxEqualTC[T], ev3: Arbitrary[T]): Prop =
{

    forAll(approxEqualLaw.commutative _)
}

def reflexivity[T](
    implicit ev1: WithDistanceTC[T], ev2: ApproxEqualTC[T], ev3: Arbitrary[T]): Prop =
{

    forAll(approxEqualLaw.reflexive _)
}
```

BONUS STAGE

```
// WATCH OUT for this one! It bites!
def transitivity[T](
   implicit ev1: WithDistanceTC[T], ev2: ApproxEqualTC[T], ev3: Arbitrary[T]): Prop =
{

   forAll(approxEqualLaw.transitive _)
}
```

BONUS STAGE

```
  def laws[T](
     implicit ev1: WithDistanceTC[T], ev2: ApproxEqualTC[T], ev3: Arbitrary[T]):
Properties = {

     new Properties("approxEqualTC") {
       property("commutativity") = commutativity[T]
       property("reflexivity") = reflexivity[T]
       property("transitivity") = transitivity[T]
     }
  }
}
```

BONUS STAGE

```
trait CheckTCLaws extends FunSuite with Checkers {
  def checkLaws[T](
     implicit ev1: WithDistanceTC[T], ev2: ApproxEqualTC[T], ev3: Arbitrary[T],
     ev4: ClassTag[T]): Unit = {

     ApproxEqualTCLawProperties.laws[T].properties foreach {
       case (name, law) =>
         test(s"$name for ${ev4.toString}") {
          check(law)
         }
     }
  }
}
```

BONUS STAGE

```
class ApproxTCTest extends CheckTCLaws {
  import IntWithDistanceTC._
  import IntApproxEqualTC._
  import DoubleWithDistanceTC._
  import DoubleApproxEqualTC._

  checkLaws[Int]
  checkLaws[Double]
}
```

Thank you! Your turn

Q & A