Partial Functions in Scala

https://github.com/logicalguess/partial-functions

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Outline

Motivation

- Functions associate a **single** output to **each** input
- In Scala inputs and outputs are type members: `Function[I, O]`
- There are many ways to create associations (e.g. formulas, tuples)
- Sometimes it is not possible or desired to associate an output to each input
- Division by zero is an example of a computation that needs to **skip** some inputs
- `Map[K, V]` is another prototypical example (many keys are **skip**ped)

The PartialFunction Type

Key Facts

- `PartialFunction[-I, +O] <: Function[-I, +O]`
- `isDefinedAt(input:I): Boolean`
- `apply(input: I): O`

Interesting Facts

- `List` and `Map` extend `PartialFunction`
- `Traversable`'s `collect` method takes a `PartialFunction` as an argument to process and skip elements at the same time
- `Sources` and `Flows` in Akka have the `collect` method too

Important PartialFunction[A, B] Methods

Methods/Operators

- `applyOrElse[A1 <: A, B1 >: B](x: A1, default: A1 => B1): B1`
- `andThen[C](k: B => C): PartialFunction[A, C]`
- `orElse[A1 <: A, B1 >: B](that: PartialFunction[A1, B1]): PartialFunction[A1, B1]`
- `lift: A => Option[B]`

Looping with Partial Functions

`PartialFunctions` have a natural body of executable code (the `apply` method) that can be called repeatedly, and a natural termination condition (when `isDefinedAt` returns `false`)

Usage Example

```
val fibs: PartialFunction[(Int, Int), (Int, Int)] = {
  case (f1: Int, f2: Int) if (f1 >= 0) => (f1 + f2, f1)
}

val restrict: PartialFunction[(Int, Int), (Int, Int)] = {
  case (f1: Int, f2: Int) if f1 < 15 => (f1, f2)
}
```

```
Iterator(restrict andThen fibs)((1, 1)) should be (21, 13)
```

Branching with Partial Functions

`PartialFunctions` can be combined, but unfortunately `orElse` is not very useful in that respect since it restricts the domain of the resulting function to the intersection type of the two functions.

Usage Example

```
val int: PartialFunction[Int, Int] = {
  case i: Int if i >= 5 => i
}

val string: PartialFunction[String, Int] = {
  case s: String => s.length
}

val bool: PartialFunction[Boolean, Int] = {
  case true => 1;
  case false => 0
}

val nothing: PartialFunction[Any, Nothing] = {
  case _ => throw new RuntimeException
}
```

```
val branch = Branch(int, string)

branch(77) shouldBe 77
branch("xyz") shouldBe 3
a [MatchError] should be thrownBy branch(true)
```

```
val branch = TypedBranch(int, string)

branch(77) shouldBe 77
branch("xyz") shouldBe 3
//branch(true) //compile time error
```

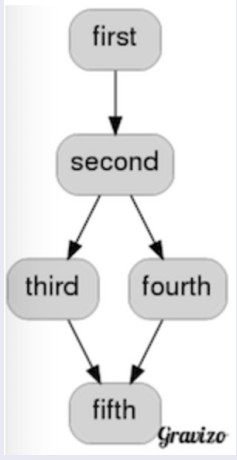
Direct Composition of (Partial) Functions

Programs consist of computation steps represented by variable manipulation, expressions, functions/method invocations, flow control, etc.
The discipline of breaking code logic into functions (including high-order ones) that can be composed and reused is (together with immutable state) the essence of functional programming.

Example

```
val convert: PartialFunction[Int, String] = {
  case i: Int if i > 0 => i.toString
}
val bang: Function[String, String] = { s: String => s + "!" }
val hash: Function[String, String] = { s: String => s + "#" }
val concatenate: Function[(String, String), String] = { s => s._1 + s._2 }

val diamondComposition: Int => String = i => {
  val s = convert(i)
  val b = bang(s)
  val h = hash(s)
  concatenate(b, h)
}
```



Conversion of (Partial) Functions to Flows

`PartialFunctions` can be (implicitly) converted to Akka flows, so the full power of the stream DSL can be used to build computational graphs using existing functions.
More generally, the conversion/lifting of functions to any `Monad` will enable out-of-the-box composition (e.g. using `for` comprehensions).

Example

```
val diamondFlow: Flow[Int, String, _] = Flow.fromGraph(GraphDSL.create() { implicit builder =>
  import GraphDSL.Implicits._

  val input = builder.add(Flow[Int])
  val bcast = builder.add(Broadcast[String](2))
  val zip = builder.add(Zip[String, String])
  val output = builder.add(Flow[String])

  input.out ~> convert ~> bcast ~> bang ~> zip.in0
  bcast ~> hash ~> zip.in1
  zip.out ~> concatenate ~> output

  FlowShape(input.in, output.out)
})
```

Class Based Objects

- Typical object-oriented programming relies on class-based languages that allow defining state and behavior logic into instance prototypes.
- The names, the inputs and outputs of the methods as well as the state management of objects are free-form and usually poorly addressed.
- Design patterns have helped to some extent, but generally speaking developers cherish this freedom.

```
class Echo {
  private var volume: Int = 5
  private var playing: Option[String] = None

  //volume logic
  def volumeUp(): Unit = volume += 1
  def volumeDown(): Unit = volume -= 1
  def setVolume(v: Int): Unit = volume = v
  def getVolume: String = s"The current volume is $volume"

  //music logic
  def play(piece: String): Unit = {
    playing = Some(piece)
  }
  def stop(): Unit = playing = None

  //temperature logic
  def getTemperature(place: String): Option[String] = {
    val temp = 70 //call service
    Some(s"The current temperature in $place is $temp degrees")
  }
}
```

Identifying The Events and State Types

Method names and parameter types can be represented by case classes or objects in Scala.

The Types

```
// events
sealed trait Event

object VolumeUp extends Event
object VolumeDown extends Event
case class SetVolume(level: Int) extends Event
object GetVolume extends Event

case class Play(piece: String) extends Event
object Stop extends Event

case class GetTemperature(place: String) extends Event

//state
case class State(volume: Int = 5,
                 playing: Option[String] = None,
                 response: Option[String] = None)
```

Writing The Logic as a Partial Function

The values return from methods are views into the state, which represents the "value" of an object instance.

The Logic

```
//function
val logic: PartialFunction[(Event, State), State] = {
  case (VolumeUp, s) => s.copy(s.volume + 1) //validate
  case (VolumeDown, s) => s.copy(s.volume - 1) //validate
  case (SetVolume(l), s) => s.copy(l) //validate

  case (GetVolume, s) => s.copy(s.volume, s.playing,
    Some(s"The current volume is ${s.volume}")) //validate

  case (Play(p), s) => s.copy(s.volume, Some(p))
  case (Stop, s) =>
    if (s.playing.isDefined) s.copy(s.volume, None) else s

  case (GetTemperature(place), s) => {
    val temp = 70 //call service
    s.copy(s.volume, s.playing,
      Some(s"The current temperature in $place is $temp degrees"))
  }
}
```

Wrapping Logic Into Entities

The types and logic can be reused and wrapped into `Flows`, `Actors` or more functional classes.

Keeping The Logic Separate From Boilerplate

```
case class EchoScan(sink: Sink[State, _])
                   (implicit mat: ActorMaterializer) {

  val source: Source[Event, SourceQueueWithComplete[Event]] =
    Source.queue[Event](10, OverflowStrategy.backpressure)

  val computation: SourceQueueWithComplete[Event] =
    source.via(logic).to(sink).run()

  def receive(event: Event): Unit = {
    computation.offer(event)
  }
}
```

```
class EchoActor extends Actor with LazyLogging {
  private var state: State = State()

  override def receive: Receive = {
    case msg: Event => {
      state = logic(msg, state)
      sender() ! state
    }
  }
}
```

```
class FunctionalEcho {
  private var state: State = State()

  def receive(event: Event): State = {
    state = logic(event, state) //could throw
    state
  }

  def getState: State = state
}
```