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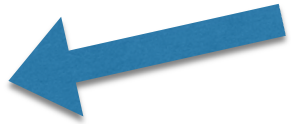
3.2
Exceptional Conditions

The functional programming way of dealing with abnormal situations

- In O-O, there are two constructs that were developed to allow for a deviation from the expected flow:
  - *null*
  - *Exception*.
- These are not FP-friendly. Why?
  - two reasons why *null* is not FP-friendly:
    - *null* is not an object and so does *not conform to type*;
    - if you try to dereference a *null* you get a NPE (null-pointer-exception)
  - *Exception* is not FP-friendly because throwing an exception is a *side-effect*!

Dealing with *null* in O-O

- Where do nulls come from in O-O?
  - missing optional values (for example in a database).
  - Basically, nulls are for lazy programmers: but they are dangerous!!
- How do we typically deal with a *null*?



Before we can do anything with *x*, we first must ensure that it is not *null*. And yet, *null* is an expected value, not unusual, at all.

```
public class Phones {

    public static void main(String[] args) {

      Map<String,Long> phones = new HashMap<>();
      phones.put("Prof. Hillyard", 6173733972L);
      // ...
      String professor = "...";
      Long x = phones.get(professor);
      if (x != null) System.out.println(professor+"'s Phone number is: "+x);
      else System.out.println("No phone number for "+professor);

    }
}
```

Optional values—The Scala way

- If the return type of a method is optional, then why not make it *explicitly* optional?

"foreach" is a pretty basic method available on all container-types. Here it means do it once or not at all, as the case may be.

```
val phones = Map("Prof. Hillyard" -> 6173733972L)
phones.get("...") foreach (x => println(s"found phone: $x")
phones.get("Prof. Hillyard") foreach (x => println(s"found phone: $x")
```

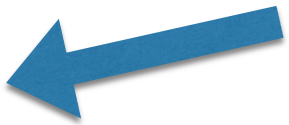
found phone: 6173733972

- In other words:
  - force the caller to deal with the possibility that there might not be a value returned…
  - …*but* make it *easy* for the user to deal with that returned value.

Dealing with exceptional conditions in O-O

- What if something goes wrong in O-O and we want to know what actually happened?
  - real life example: unable to get connection to remote database.
  - we catch/handle the exception (e.g. print stack trace) if we can, otherwise, we pass it up to the caller.
- What does this look like in practice?

```
Map<String,Long> phones = new HashMap<>();
phones.put("Prof. Hillyard", 6173733972L);
// ...
String professor = "...";
long x = phones.get(professor);
```



Unboxing to *long* (which the compiler has no problem with) causes a null-pointer-exception when the professor is not found.

Exceptions—The Scala way

- Let's deal with these errors (exceptional conditions) in a calm, *referentially-transparent* way, with no loss of information:

```
def log(x: Double) = if (x > 0) Math.log(x) else throw new Exception("x must be positive")
def tryLog(x: Double) = Try(log(x))
val result = tryLog(-1)
result foreach (x => println(s"log value is $x"))
tryLog(math.E) foreach (x => println(s"log value is $x"))
```

log value is 1.0

"foreach" is used in the same way as in *Optional* class. There are ways to recover the actual cause of the *Failure* if we need to.

- In other words:
  - this looks just like the situation where we returned *Option[Long]*
  - the difference is that we have ways to recover the exception from the *Try* object (including throwing it if we really want to).

Option

- Suppose we want to find an element in a list that satisfies a predicate?
  - What if there's no such element (the list might be empty, or the predicate simply never yields *true* for any element)?
  - In Scala, the *find* method on *List[X]* returns an *Option[X].*
  - How should we implement *Option[X]*?
  - What should its API be?
    - *isDefined: Boolean*
    - *isEmpty: Boolean = !isDefined*
    - *get: X [will throw exception if empty]*
    - *getOrElse[Y >: X](default: => Y): Y = if (isDefined) get else default*
    - *map[Y](f: X=>Y): Option[Y]*

Option (2)

- So, we can define some methods we will want to call. Let's make them into a **trait**.

```
trait Option[X] {
  def isDefined: Boolean
  def get: X
  …
  }
```

- What have we got? A container of which essentially there are two* types: an empty container and a non-empty container that holds an *X* in it.

* it's nearly always *two* types

Option (3)

- Let's call our two containers *Some* and *None* and implement them as *case classes/objects* extending *Option*.

```
case class Some[X](x: X) extends Option[X] {
 def isDefined: Boolean = true
 def get: X = x
 }
case object None extends Option[Nothing] {
 def isDefined: Boolean = false
 def get: Nothing = throw new NoSuchElementException("None.get")
 }
```

Do you recognize a patten here? We did something just like this for *List*: we defined *Cons* and *Nil*.

- Now, we can use pattern matching to figure what we've got:

```
List(1,2,3).find(_%2==0) match {
 case Some(x) => println(x)
 case None => println("no even number found")
 }
```

Option (4)

- Using *Option* to handle objects returned from Java methods:

```
object Option {

  import scala.language.implicitConversions

 /** An implicit conversion that converts an option to an iterable value
  */
 implicit def option2Iterable[A](xo: Option[A]): Iterable[A] = xo.toList

  /** An Option factory which creates Some(x) if the argument is not null,
   *  and None if it is null.
   *
   *  @param  x the value
   *  @return   Some(value) if value != null, None if value == null
   */
 def apply[A](x: A): Option[A] = if (x == null) None else Some(x)
}
```

- val x = javaFunction(); // could return null
- val xo = Option(x)

Try

- Suppose we want to convert a *String* to an *Int* and know that it might throw an exception?
  - In Java we can wrap the expression in try..catch..finally
  - In Scala, we can actually do the same thing. But there's a much better, more functional way: *Try[X].*
  - How should we implement *Try[X]*?
  - What should its API be?
    - *isSuccess: Boolean*
    - *isFailure: Boolean = !isSuccess*
    - *get: X [will throw exception if failure]*
    - *getOrElse[Y >: X](default: => Y): Y = if (isSuccess) get else default*
    - *map[Y](f: X=>Y): Try[Y]*
    - *…*

Try (2)

- So, we can define some methods we will want to call. Let's make them into a **trait**.

```
trait Try[X] {
 def isSuccess: Boolean
 def get: X
 …
 }
```

Sound familiar? We defined *Option* just like this.

- What have we got? A container of which essentially there are two types: a successful container with an X in it and a failure container that holds the exception.

Try (3)

- Let's call our two containers *Success* and *Failure*. They will be case classes extending *Try*.

```
case class Success[X](x: X) extends Try[X] {
 def isSuccess: Boolean = true
 def get: X = x
 }
case class Failure[X](e: Throwable) extends Try[X] {
 def isSuccess: Boolean = false
 def get: X = throw e
 }
```

Look familiar? We extracted the contents of *Option* rather like this. The big difference is that in the fail case, we actually have an exception

- Now, we can use pattern matching to figure what we've got:

```
Try("a".toInt) match {
 case Success(x) => println(x)
 case Failure(e) => e.printStackTrace()
 }
```

Try (4)

- Using *Try* to handle methods which may throw an exception (usually but not always Java methods):

```
object Try {
  /** Constructs a `Try` using the by-name parameter. This
   * method will ensure any non-fatal exception is caught and a
   * `Failure` object is returned.
   */
  def apply[T](r: => T): Try[T] =
      try Success(r) catch {
        case NonFatal(e) => Failure(e)
      }
}
```

Note that the parameter to the *Try.apply* method is call-by-name: this allows the actual exception to be caught *inside* the apply method.

- val xy = Try(“s”.toInt)

Summary

- Scala defines two traits, each with two case classes/objects to represent the exceptional conditions corresponding to Java's *null* and *Exception.*
- As we shall see, these containers are very natural and easy to use and they are *referentially transparent!*
- Oh yes, and they are *monads*! (We'll talk about these later).