26-Exceptional conditions

The FP 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*?

```
public class Nulls {

    /**
     * Optionally return the current time in milliseconds
     * @return current time if it's odd; otherwise we return null
     */
     public static Long getTime() {
         long l = System.currentTimeMillis();
         if (l % 2 == 0)
             return null;
         else
             return l;
     }

     public static void main(String[] args) {
         Long time = getTime();
         if (time != null)
             System.out.println(time);
         else
             System.err.println("cannot get time");
     }
}
```

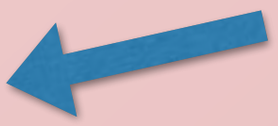
This is a totally arbitrary (and silly) example.But it's also very simple and therefore appropriate for our study.

Optional values—The Scala way

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

```
class Optional {
  def getTime: Option[Long] = {
    val l: Long = System.currentTimeMillis
    if (l % 2 == 0) None
    else Some(l)
  }
}

object Optional extends App {
  val to = new Optional().getTime
  to foreach { System.out.println(_) }
}
```



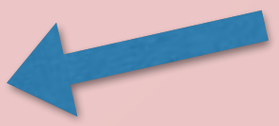
"foreach" is a pretty basic method available on all container-types. Here it means do it once or not at all, as the case may be.

- 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?

```
public class Exceptions {
/**
 * Try to return the current (odd) time in milliseconds
 * @throws RuntimeException if time is even
 */
 public static Long getTime() {
     long l = System.currentTimeMillis();
     if (l % 2 == 0)
         throw new RuntimeException("time was even");
     else
         return l;
 }
 public static void main(String[] args) {
     try {
         Long time = getTime();
         System.out.println(time);
     }
     catch (Exception e) {
         e.printStackTrace();
     }
 }
}
```



Here, of course, we are in a *main* program so there's nobody to pass it up to. We are obliged to handle it somehow.

Exceptions—The Scala way

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

```
class MyTry {
  def getTime: Try[Long] = {
    val l: Long = System.currentTimeMillis
    if (l % 2 == 0) Failure(new Exception("time was was even"))
    else Success(l)
  }
}

object MyTry extends App {
  val ty = new MyTry().getTime
  ty foreach {System.out.println(_)}
}
```

"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.

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
  …
}
```

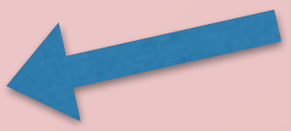
Sound familiar? We defined *Option* just like this.

- What have we got? A container of which essentially there are two types: an 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

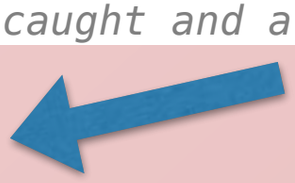
- Now, we can use pattern matching to figure what we've got:

```
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!*