Fuss-free data validation without using exceptions

Scala, Rust, Swift, Haskell

Franklin Chen
http://franklinchen.com/

Pittsburgh Code and Supply

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Outline

Goals

- Explain concepts using fully worked-out example
- Show real code (it's all up on GitHub)
- Hope you learn something you go out and *use*

Why cover four languages?

Pittsburgh Code and Supply's polyglot advantage

- Opportunity for you to explore a new language, and compare different designs
- More efficient than giving multiple presentation about the exact same concepts

Why Scala, Rust, Swift, Haskell?

- First-class functions
- Tagged union types

But any language with first-class functions can be used:

- JavaScript, etc.

Swift is still changing

Limited Swift code examples: language and compiler not stable (Swift 1.2 was officially released *yesterday* !)

A data validation example task

From Martin Fowler's article, "Replacing Throwing Exceptions with Notification in Validations":

- Goal: create a valid event from a theater booking request
- Given: a date string that is possible null, a number of seats that is possible null
- Validate:
  - Possibly null date string
    - Date string must not be null
    - Date string must actually parse to a date
    - Request date must not be earlier than now
  - Possibly null number of seats
    - Number of seats must not be null
    - Number of seats must be positive

Java code

```
public void check() {
  if (date == null)
    throw new IllegalArgumentException("date is missing");
  LocalDate parsedDate;
  try {
    parsedDate = LocalDate.parse(date);
  }
  catch (DateTimeParseException e) {
    throw new IllegalArgumentException("Invalid format for da
  }
  if (parsedDate.isBefore(LocalDate.now()))
    throw new IllegalArgumentException("date cannot be before
  if (numberOfSeats == null)
    throw new IllegalArgumentException("number of seats canno
  if (numberOfSeats < 1)
    throw new IllegalArgumentException("number of seats must
}
```

Normal execution

- A thread of execution, toward a destination
- Stack of pending operations
- When an operation is complete, pops off the stack

Exceptions considered problematic

Exceptions mean jumping up the stack

- Have to explicitly watch for and catch them
- Tedious to collect more than one error if exceptions are used
- What happens when there is concurrency?

Some languages don't have exceptions

- C
- Go
- Rust
- Swift

Railway-oriented programming

Railway-oriented programming:

- Keeping computation on the tracks.
- Cleanly handle track-switching and merging.

null: the unloved second track

- null is Tony Hoare's billion-dollar mistake, invented in 1965
- Adds a second track to every single computation involving a reference type
- Null Pointer Exceptions, seg faults

No more mention of null here!

- All four languages mentioned have an improvement we take as a starting point.

`Option[T]`

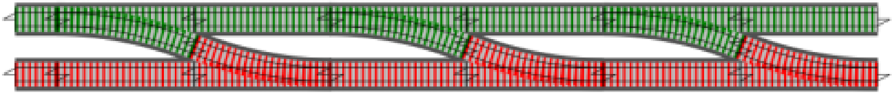
	Scala	Rust	Swift	Haskell
Type	`Option[T]`	`Option<T>`	`Optional<T>`[1]	`Maybe t`
Nonexistence	`None`	`None`	`.None`[2]	`Nothing`
Existence	`Some(x)`	`Some(x)`	`.Some(x)`[3]	`Just x`

[1] Abbreviated `T?`

[2] Abbreviated `nil`

[3] Special syntactic sugar available

Chaining computations over Option[T]



Example

Railway chaining values of an Option type

- If encountering a None:
  - Bail out permanently to the failure track
- Else if encountering a Some(x):
  - Stay on the success track

Scala: chaining syntactic sugar for `Option[T]`

Example

"Find the winner: your best friend's oldest sister's youngest child"

```scala
/** Assume: bestFriend(), oldestSister(), youngestChild()
  each returns Option[Person] */
def winner(person: Person): Option[Person] = for {
  friend <- person.bestFriend()
  sister <- friend.oldestSister()
  child <- sister.youngestChild()
} yield child
```

- Scala's "`for` comprehensions" inspired by Haskell
- Generic for railway-oriented programming

Scala: non-sugar chaining for `Option[T]`

Example

"Find the winner: your best friend's oldest sister's youngest child"

```
/** Assume: bestFriend(), oldestSister(), youngestChild()
  each returns Option[Person] */
def unsweetWinner(person: Person): Option[Person] =
  person.bestFriend()   .flatMap( friend =>
  friend.oldestSister() .flatMap( sister =>
  sister.youngestChild()
  ))
```

- Sugar is preprocessed to this code *before compilation*

Swift: chaining syntactic sugar for T?

Example

"Find the winner: your best friend's oldest sister's youngest child"

```
/** Assume: bestFriend(), oldestSister(), youngestChild()
  each return Person? */
func winner(person: Person) -> Person? = {
  return person.bestFriend()?.
                oldestSister()?.
                youngestChild()
}
```

- Swift's special chaining sugar
- Specific to `Optional` only!

Rust: no syntactic sugar for Option<T>

Example

"Find the winner: your best friend's oldest sister's youngest child"

```
/// Assume: best_friend(), oldest_sister(), youngest_child()
/// each returns Option<Person>
fn winner(person: Person) -> Option<Person> {
  person.best_friend()       .and_then( |friend|
     friend.oldest_sister() .and_then( |sister|
     sister.youngest_child()
  ))
}
```

- Rust: no syntactic sugar
- Deprecate use of Option for error signaling!
- Sugar provided for what Rust recommends instead (next topic)

Haskell: chaining syntactic sugar for Maybe t

Example

"Find the winner: your best friend's oldest sister's youngest child"

```
-- | Assume: bestFriend, oldestSister, youngestChild
-- each returns 'Maybe Person'
winner :: Person -> Maybe Person
winner person = do
  friend <- person & bestFriend
  sister <- friend & oldestSister
  sister & youngestChild
```

- Haskell's "do notation" invented in 1993

`Option` considered harmful

Warning

An `Option`-chained failure gives *zero information* about *why* and *where* something failed!

When `winner(person)` returns `None`:

- Did the person's best friend's oldest sister not have any children?
- Or did the person's best friend not have any sisters?
- Or did the person not have any friends?

Knowledge is power

"Enquiring minds want to know!"

`Either[E, T]`

	Scala	Swift	Haskell
Type	`Either[E, T]`[4]	`Either<E, T>`[5]	`Either e t`
Bad Good	`Left(e)` `Right(x)`	`.Left(e)` `.Right(x)`	`Left e` `Just x`

	Rust
Type	`Result<T, E>`[6]
Bad Good	`Err(e)` `Ok(x)`

[4] The Scalaz library provides an improved version called `E \/ T` we will prefer

[5] `Either<E, T>` *not* in Swift's standard library, but provided in Swiftx

[6] Rust chose a more informative name, and placed success type param `T` first

Converting between `Option[T]` to `E \/ T`

Conversion is simple

Examples using Scalaz:

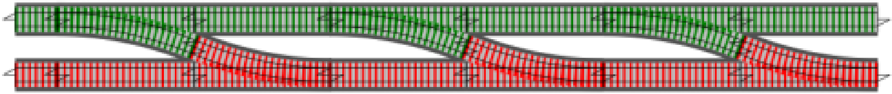
`E \/ T` to `Option` "Forget" an error by replacing it with `None`:

```
optX = eitherX.toOption
```

`Option[T]` to `E \/ T` "Add" an error by replacing `None` with an error:

```
eitherX = optX.toRightDisjunction("some error")
```

Chaining computations over `Either[E, T]`



Exact same concept as with `Option[T]`.

Scala: chaining syntactic sugar for E \/ T

Example

"Find the winner: your best friend's oldest sister's youngest child"

```
/** Assume: bestFriend(), oldestSister(), youngestChild()
  each returns MyError \/ Person */
def winner(person: Person): MyError \/ Person = for {
  friend <- person.bestFriend()
  sister <- friend.oldestSister()
  child <- sister.youngestChild()
} yield child
```

- Exact same code as with `Option[T]`!
- We are using Scalaz library's disjunction `E \/ T` because standard Scala's `Either[E, T]` has limitations
- Genericity of railway-oriented code: large topic in itself

Swift: no syntactic sugar for `Either<E, T>`

Example

"Find the winner: your best friend's oldest sister's youngest child"

```
/** Assume: bestFriend(), oldestSister(), youngestChild()
  each return Either<MyError, Person> */
func winner(person: Person) -> Either<MyError, Person> = {
  return person.bestFriend() .flatMap { friend in
    friend.oldestSister()    .flatMap { sister in
    sister.youngestChild()
  }}
}
```

- Use Swiftx library
- Swift does *not* have general railway-oriented syntactic sugar

Rust: chaining syntactic sugar for Result<T, E>

Example

"Find the winner: your best friend's oldest sister's youngest child"

```
/// Assume: best_friend(), oldest_sister(), youngest_child()
/// each returns Result<Person, MyError>
fn winner(person: Person) -> Result<Person, MyError> {
  let friend = try!(person.best_friend());
  let sister = try!(friend.oldest_sister());
  sister.youngest_child()
}
```

Rust

- Can use exactly the same non-sugar code as for `Option<T>` if wanted
- Standard library has macro `try!` for use with `Result<T, E>`
- *Does not have exceptions*, so ease of use of `Result<T, E>` is critical!

Haskell: chaining syntactic sugar for `Either e t`

Example

"Find the winner: your best friend's oldest sister's youngest child"

```haskell
-- | Assume: bestFriend, oldestSister, youngestChild
-- each returns 'Either MyError Person'
winner :: Person -> Either MyError Person
winner person = do
  friend <- person & bestFriend
  sister <- friend & oldestSister
  sister & youngestChild
```

- Exact same code as with `Maybe t`!

Constructors considered harmful

- Constructors in many languages do not return a result, so failures are indicated by either:
  - Throwing an exception
  - Return `null` and setting an error object elsewhere
- Alternative: "factory method" that returns an `Either[SomeError, ThingToCreate]`

Constructing Seat: Scala

```scala
case class Seats private(val num: Int) extends AnyVal

object Seats {
  sealed trait Error
  case class BadCount(num: Int) extends Error {
    override def toString =
      s"number of seats was $num, but must be positive"
  }

  def make(num: Int): BadCount \/ Seats = {
    if (num < 0)
      BadCount(num).left
    else
      Seats(num).right
  }
}
```

Notes on clean module design

- The constructor for `Seats`:
  - Is trivial, not bloated: just saves off parameters into fields
  - Is private, to guarantee only approved factory methods can call it
- Errors:
  - Each module defines its own set of errors as a union type, here called `Error`
  - (Here only one, `BadCount`)
- Factory methods:
  - Each `Seats` factory method returns `Error \/ Seats`

Constructing Seat: Rust

```
pub struct Seats {
  num: i32 // private
}

pub enum Error {
  BadCount(i32)
}

impl Seats {
  pub fn make(num: i32) -> Result<Seats, Error> {
    if num < 0 {
      Err(Error::BadCount(num))
    } else {
      Ok(Seats { num: num })
    }
  }
}
```

Constructing Seat: Haskell

```haskell
-- | Wrapper around 'Int' that ensures always positive.
newtype Seats = Seats { getNum :: Int }

data Error = BadCount Int -- ^ attempted number of seats

instance Show Error where
  show (BadCount seats) = "number of seats was " ++
      show seats ++ ", but must be positive"

-- | Smart constructor for 'Seats' that
-- ensures always positive.
make :: Int -> Validation Error Seats
make seats | seats < 0 = Failure $ BadCount seats
           | otherwise = Success $ Seats seats
```

Constructing Seat: Swift

No example: because didn't want to dive into the flaws of

- failable initializers
- Cocoa factory methods

`Either` considered insufficient

Warning

An `Either`-chained failure returns information *only* about the first failure ("fail fast").
What if we want to chain multiple result-returning computations while collecting *all* failures along the way?

Examples:

- Booking request example: date and number of seats may both be invalid; we want to know about both failures
- Facebook: *concurrently* accesses many data sources, collecting all failures[7]

The goal

"Enquiring minds want to know *everything* !"

[7] Facebook open-sourced their Haskell library Haxl for this

Introduction

Validation libraries:

- **Scala** Scalaz library
- **Rust** I wrote my own library, may generalize and publish it
- **Swift** Swiftz (superset of Swiftx) is based on Scalaz
- **Haskell** validation library

Differences in naming and design

Because of differences, we will use Scalaz terminology.

Definition

`Validation[E, T]`

Continue to track success/failure in an `Either[E, T]`-like object:

- Leave *sequential* railway-oriented computation model
- Adopt *parallel* computation model

`ValidationList[E, T]`

Just a synonym for `Validation[List[E], T]`:

- Replace individual failure with a collection of failures

Annoying names

In the Scalaz library, the real name for `ValidationList[E, T]` is `ValidationNel[E, T]`:

- "Nel" stands for `NonEmptyList`
- `ValidationNel[E, T]` is a synonym for `Validation[NonEmptyList[E], T]`

All the different `Either` types

	`Either[E, T]`	`E \/ T`	`Validation[E, T]`
Bad Good	`Left(e)` `Right(x)`	`-\/(e)` `\/-(x)`	`Failure(e)` `Success(x)`
Purpose	symmetric, neutral	railway-oriented	accumulation

Conversion among them is simple: just replacing the tag.

BookingRequest types: Scala

```scala
case class BookingRequest private(
  val date: Date,
  val seats: Seats
)

sealed trait Error

// These wrap errors from other modules.
case class DateError(e: Date.Error) extends Error
case class SeatsError(e: Seats.Error) extends Error

// Our additional errors.
case class DateBefore(date1: Date, date2: Date) extends Error
case class Missing(label: String) extends Error
```

BookingRequest types: Rust

```
pub struct BookingRequest {
  date: Date,
  seats: seats::Seats
}

pub enum Error {
  DateError(date::Error),
  SeatsError(seats::Error),
  DateBefore(Date, Date),
  Missing(String)
}
```

BookingRequest types: Haskell

```haskell
data BookingRequest =
  BookingRequest { getDate :: Date.Date
                 , getSeats :: Seats.Seats
                 }

data Error =
    DateError Date.Error
  | SeatsError Seats.Error
  | Missing String         -- ^ label
  | DateBefore Date.Date   -- ^ date that was attempted
               Date.Date   -- ^ the current date at attempt
```

Seats creation

```
def makeSeats(optSeats: Option[Int]):
    Error \/ Seats = for {
  num <- optSeats.toRightDisjunction(Missing("seats"))
  validSeats <- Seats.make(num).leftMap(SeatsError)
} yield validSeats
```

Use chaining:

- Convert the `Option[Int]` to `Error \/ Int`
- Use `leftMap` to lift from `Seats.Error \/ Seats` to `Error \/ Seats`

Date validation against now

```
def timelyBookingDate(date: Date, now: Date):
    DateBefore \/ Date = {
  if (!date.isBefore(now))
    date.right
  else
    DateBefore(date, now).left
}
```

A validator that just passes along what comes in if it's OK.

Date creation

```
def makeTimelyBookingDate(now: Date,
  optDateString: Option[String]): Error \/ Date = for {
  dateString <- optDateString.
                toRightDisjunction(Missing("date"))
    date <- Date.parse(dateString).leftMap(DateError)
    timelyDate <- timelyBookingDate(date, now)
} yield timelyDate
```

Use chaining:

- First, get the requested date
- Then validate that against now

BookingRequest factory method

```
def make(
  now: Date,
  optDateString: Option[String],
  optSeats: Option[Int]
): ValidationNel[Error, BookingRequest] = {
  val combinedBuilder =
    makeTimelyBookingDate(now, optDateString).
      validation.toValidationNel |@|
    makeSeats(optSeats).
      validation.toValidationNel

  combinedBuilder(BookingRequest(_, _))
}
```

Combination of techniques:

- Sequential: each of `Seats`, `Date` validated creation is railway-oriented
- Parallel: in principle, the combiner can be parallelized

Technical notes

Concepts covered, in order from more specific to more general:

- Sequential, railway-oriented programming is called *monadic*: `Option` and `Either` are the simplest monads; there is a vast number of more complex monads
- Parallelizable composition is called *applicative*: `Validation` is an applicative functor
- Parallelizable combination is called *monoidal*: `List` is a monoid
- (`NonEmptyList` is a semigroup, a monoid without identity element)

Conclusion

Summary:

- We saw how to break down a messy validation problem
- Design with types to reflect intent
- Use result objects that track failures, force error handling
- Factory methods to create only valid objects
- Sequential railway-oriented chaining of validator functions
- Parallel computations can be expressed by separating independent components
- Minimizing `if`/`else`-style programming feels good!

Slides and code

Slides in source and PDF form:

- https://github.com/FranklinChen/data-validation-demo

Complete code with tests run on Travis CI:

Scala	https://github.com/FranklinChen/data-validation-demo-scala
Rust	https://github.com/FranklinChen/data-validation-demo-rust
Haskell	https://github.com/FranklinChen/data-validation-demo-haskell
Swift	https://github.com/FranklinChen/data-validation-demo-swift