Exploring type-directed, test-driven development

A case study using FizzBuzz

Franklin Chen
http://franklinchen.com/

June 7, 2014
Pittsburgh TechFest 2014

Outline

Goals of this presentation

- Give a taste of a practical software development process that is:
  - test-driven
  - type-directed
- Show everything for real (using Scala):
  - project build process
  - testing frameworks
  - all the code
- Use `FizzBuzz` because:
  - problem: easy to understand
  - modifications: easy to understand
  - fun!
- Encourage you to explore a modern typed language
  - This Monday, Apple ditched Objective C for its new language Swift!
  - Complete Swift code will shown at the end; looks a lot like Scala.

Test-driven development (TDD)

- Think.
- Write a test that fails.
- Write code until test succeeds.
- Repeat, and refactor as needed.

Is TDD dead?

Short answer: No.

Type systems

What is a type system?

A syntactic method to prove that bad things can't happen.

"Debating" types "versus" tests?

- Let's use both types and tests!
- But: use a good type system, not a bad one.

Some decent practical typed languages

- OCaml: 20 years old
- Haskell: 20 years old
- Scala: 10 years old
- Swift: 5 days old
- Rust (still in progress)

Poor versus decent type systems

Poor type systems

- (Developed using 1960s-1970s knowledge)
- C, C++, Objective C
- Java

Decent type systems

- (Developed using 1980s-1990s knowledge)
- ML (Standard ML, OCaml, F#): I first used for work in 1995
- Haskell: I first used for work in 1995
- Scala: first released in 2004
- Swift: announced by Apple on June 2, 2014!
- Rust: not yet version 1.0

Original FizzBuzz problem

FizzBuzz defined

Write a program that prints the numbers from 1 to 100.
But for multiples of three, print "Fizz" instead of the number.
And for the multiples of five, print "Buzz".
For numbers which are multiples of both three and five, print "FizzBuzz".

Starter code: main driver

Scala

Scala: a modern object-oriented and functional language.

```
object Main extends App {
  // Will not compile yet!
  runToSeq(1, 100).foreach(println)
}
```

- Type-directed design: separate out effects (such as printing to terminal) from the real work.
- Type-directed feedback: compilation fails when something is not implemented yet.

The joys of continuous compilation and testing

sbt

SBT: build tool supporting Scala, Java...

Winning features

- Source file changes trigger smart recompilation!
- Source file changes trigger rerun of the tests that depend on changed code!

```
$ sbt
> ~testQuick
[info] Compiling 1 Scala source to ...
[error] ...Main.scala:16: not found: value runToSeq
[error]   runToSeq(1, 100) foreach println
[error]   ^
[error] one error found
```

Write type-directed stub

```scala
object Main extends App {
  runToSeq(1, 100).foreach(println)

  def runToSeq(start: Int, end: Int): Seq[String] = {
    ???
  }
}
```

Write wanted type signature

`???` is convenient for stubbing.

- In Scala standard library
- Just performs: `throw new NotImplementedError`

Write acceptance test (simplified)

specs2

Specs2: a fine testing framework for Scala, Java...

```
class MainSpec extends Specification { def is = s2"""
  ${Main.runToSeq(1, 16) ==== `strings for 1 to 16`}
  """

  val `strings for 1 to 16` = Seq(
    "1", "2", "Fizz", "4", "Buzz", "Fizz",
    "7", "8", "Fizz", "Buzz", "11", "Fizz",
    "13", "14", "FizzBuzz", "16"
  )
}
```

TDD in Swift

```swift
class MainSpec: XCTestCase {
  func test1to16() {
    let expected: String[] = [
      "1", "2", "Fizz", "4", "Buzz", "Fizz",
      "7", "8", "Fizz", "Buzz", "11", "Fizz",
      "13", "14", "FizzBuzz", "16"
    ]

    XCTAssert(Main.runToSeq(1, 16) == expected)
  }
}
```

Test passes type check, but fails

Incremental compilation/testing kicks in:

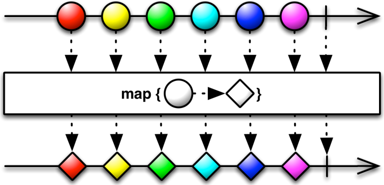
```
Waiting for source changes... (press enter to interrupt)
[info] MainSpec
[info]   x Main.runToSeq(1, 16) ==== ‘strings for 1 to 16
[error]  an implementation is missing (Main.scala:19)
```

Outside-in: for a FizzBuzz unit

Types are shapes to assemble logically.

```
def runToSeq(start: Int, end: Int): Seq[String] = {
  start.to(end).map(FizzBuzz.evaluate)
}
```

- `start.to(end): Seq[Int]`, where `Seq[_]` is a type constructor that, given a type `A`, returns a type of `Seq[A]`.
- For any value of type `Seq[A]`, `map: (A => B) => Seq[B]`.



- Therefore: need to implement function `FizzBuzz.evaluate: Int => String`.

Swift version of driver

```
func runToSeq(i: Int, j: Int) -> String[] {
  return Array(i...j).map(Defaults.fizzBuzzer)
}
```

Implement new FizzBuzz module

A failing acceptance test drives discovery of

- A unit, FizzBuzz
- A function with a particular type, Int => String

```
object FizzBuzz {
  type Evaluator = Int => String

  val evaluate: Evaluator = { i =>
    ???
  }
}
```

Types are better than comments as documentation!

Comments are not checkable, unlike types and tests.

First part of unit test: example-based

Manually write some examples.

```
class FizzBuzzSpec extends Specification { def is = s2"""
  ${FizzBuzz.evaluate(15) ==== "FizzBuzz"}
  ${FizzBuzz.evaluate(20) ==== "Buzz"}
  ${FizzBuzz.evaluate(6) ==== "Fizz"}
  ${FizzBuzz.evaluate(17) ==== "17"}
  """
}
```

The joy of property-based tests

SCALA CHECK

ScalaCheck: a framework for writing property-based tests.

```
class FizzBuzzSpec extends Specification
    with ScalaCheck { def is = s2"""
  ${`Multiple of both 3 and 5 => "FizzBuzz"`} """
  def `Multiple of both 3 and 5 => "FizzBuzz"` =
    prop { i: Int => (i % 3 == 0 && i % 5 == 0) ==>
      { FizzBuzz.evaluate(i) ==== "FizzBuzz" }
    }
}
```

Winning features

- Auto-generates random tests for each property (100 by default).
- Type-driven: here, generates random Int values.

Property-based testing for Swift?

I hope someone writes a property-based testing framework for Swift!

Property-based tests (continued)

The other three properties of interest:

```
def `Multiple of only 3 => "Fizz"` =
  prop { i: Int => (i % 3 == 0 && i % 5 != 0) ==>
    { FizzBuzz.evaluate(i) ==== "Fizz" }
  }

def `Multiple of only 5 => "Buzz"` =
  prop { i: Int => (i % 3 != 0 && i % 5 == 0) ==>
    { FizzBuzz.evaluate(i) ==== "Buzz" }
  }

def `Not a multiple of either 3 or 5 => number` =
  prop { i: Int => (i % 3 != 0 && i % 5 != 0) ==>
    { FizzBuzz.evaluate(i) ==== i.toString }
  }
```

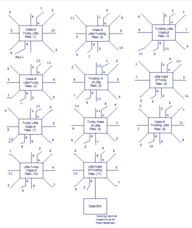
A buggy and ugly solution

```scala
// Buggy and ugly!
val evaluate: Evaluator = { i =>
  if (i % 3 == 0)
    "Fizz"
  else if (i % 5 == 0)
    "Buzz"
  else if (i % 3 == 0 && i % 5 == 0)
    "FizzBuzz"
  else
    i.toString
}
```

```
[info] FizzBuzzSpec
[info]   x FizzBuzz.evaluate(15) ==== "FizzBuzz"
[error]  'Fizz' is not equal to 'FizzBuzz'
            (FizzBuzzSpec.scala:14)
```

Booleans are evil!

Maze of twisty little conditionals, all different



- Too easy to write incorrect sequences of nested, combined conditionals.
- Overuse of Booleans is a type smell.

Why booleans are evil

No help from type system

- Conditions can be arbitrary: depend on any combination of data.
- Multiple conditions: combinatorial explosion (two conditions led to four cases).
- Possibly overlapping conditions: order dependency subtleties.
- Possibly duplicated checking of the some condition.

Pattern matching organizes information

```
val evaluate: Evaluator = { i =>
  (i % 3 == 0, i % 5 == 0) match {
    case (true,  false) => "Fizz"
    case (false, true)  => "Buzz"
    case (true,  true)  => "FizzBuzz"
    case (false, false) => i.toString
  }
}
```

Winning features

- Visual beauty and clarity.
- No duplicated conditionals.
- No ordering dependency.
- Type checker verifies full coverage of cases.

Example of non-exhaustive pattern matching

```scala
val evaluate: Evaluator = { i =>
  (i % 3 == 0, i % 5 == 0) match {
    case (true,  false) => "Fizz"
    case (false, true)  => "Buzz"
    case (true,  true)  => "FizzBuzz"
    // case (false, false) => ???
  }
}
```

```
[warn] ...FizzBuzz.scala:46: match may not be exhaustive.
[warn] It would fail on the following input: (false, false)
[warn]      (i % 3 == 0, i % 5 == 0) match {
[warn]      ^
```

Swift digression: pattern matching

The same solution, in Swift:

```
typealias Evaluator = Int -> String

let evaluate: Evaluator = { i in
  switch (i % 3 == 0, i % 5 == 0) {
  case (true,  false): return "Fizz"
  case (false, true):  return "Buzz"
  case (true,  true):  return "FizzBuzz"
  case (false, false): return String(i)
  }
}
```

Acceptance test passes

```
[info] MainSpec
[info]   + Main.runToSeq(1, 16) ==== ‘strings for 1 to 16
```

Done?

No. Client wants more features.

Adding new features

Client wants to:

- Choose two arbitrary divisors in place of `3` and `5`
  - such as `4` and `7`
- Choose other arbitrary words in place of `"Fizz"` and `"Buzz"`
  - such as `"Moo"` and `"Quack"`

Type-driven refactoring

Types mean: refactoring is much more fun!

- Add new tests.
- Change types and code: to make new tests type check.
- Refactor original code and tests: use new APIs.
- Keep passing the old tests.
- Delay writing code for new features.

More features means more types

Change FizzBuzz.evaluate to Defaults.fizzBuzzer:

```
def runToSeq(start: Int, end: Int): Seq[String] = {
  start.to(end).map(Defaults.fizzBuzzer)
}
```

Add new types to FizzBuzz module:

```
type Evaluator = Int => String
case class Config(pair1: (Int, String),
                  pair2: (Int, String))
type Compiler = Config => Evaluator

val compile: Compiler = {
  case Config((d1, w1), (d2, w2)) =>
    {  i =>
      ???
    }
}
```

Extract original default configuration

```scala
object Defaults {
  val fizzBuzzerConfig: Config =
    Config(3 -> "Fizz", 5 -> "Buzz")

  val fizzBuzzer: Evaluator =
    FizzBuzz.compile(fizzBuzzerConfig)

  // Useful to keep old implementation
  val oldFizzBuzzer: Evaluator = { i =>
    (i % 3 == 0, i % 5 == 0) match {
      case (true,  false) => "Fizz"
      case (false, true)  => "Buzz"
      case (true,  true)  => "FizzBuzz"
      case (false, false) => i.toString
    }
  }
}
```

More types means more tests

Write new property-based test over arbitrary user configurations:

```
val arbitraryConfig: Arbitrary[Config] = Arbitrary {
  for {
    (d1, d2, w1, w2) <-
      arbitrary[(Int, Int, String, String)]
  } yield Config(d1 -> w1, d2 -> w2)
}

def `Arbitrary pair of divisors: divisible by first` =
  arbitraryConfig { config: Config =>
    val evaluate = FizzBuzz.compile(config)
    val Config((d1, w1), (d2, _)) = config
    prop { i: Int => (i % d1 == 0 && i % d2 != 0) ==>
      { evaluate(i) ==== w1 }
    }
  }
```

Problem: coarse `Config` type

```
[info]   ! Arbitrary divisor/word pair fizzBuzzers
[error]  ArithmeticException: :
         A counter-example is 'Config((0,),(0,))':
         java.lang.ArithmeticException: / by zero
         (after 0 try)  (FizzBuzzSpec.scala:58)
```

- `0` as a divisor crashes!
- We discovered client's underspecification.
- Client says: meant to allow only divisors within `2` and `100`.

We need to:

- Add runtime validation when constructing `Config`.
- Refine `Config` random generator.

Add (runtime) validation

Runtime precondition contract: Scala's `require` (throws exception on failure):

```
val DIVISOR_MIN = 2; val DIVISOR_MAX = 100

def validatePair(pair: (Int, String)) = pair match {
  case (d, _) =>
    require(d >= DIVISOR_MIN,
      s"divisor $d must be >= $DIVISOR_MIN")
    require(d <= DIVISOR_MAX,
      s"divisor $d must be <= $DIVISOR_MAX")
}

case class Config(pair1: (Int, String),
                  pair2: (Int, String)) {
  validatePair(pair1); validatePair(pair2)
}
```

A note on exceptions and types

- Exceptions are evil because they escape the type system.
- In real life, I prefer to use a principled type-based validation system, such as Scalaz.
- Note: Swift does not have exceptions, so expect some type-based libraries to emerge!

Data validation can be critical!

Digression: two ways to prevent Heartbleed

- Instead of C: use a dependently typed safe systems language such as ATS for compile-time TDD.
- Even with C: use good validation and testing practices.
  - A weaker type system is not an excuse to skip write tedious validation code or tests!

Improve Config random generator

```
val arbitraryConfig: Arbitrary[Config] =
  Arbitrary {
    for {
      d1 <- choose(DIVISOR_MIN, DIVISOR_MAX)
      d2 <- choose(DIVISOR_MIN, DIVISOR_MAX)
      w1 <- arbitrary[String]
      w2 <- arbitrary[String]
    } yield Config(d1 -> w1, d2 -> w2)
  }
```

New test runs further, stills fails

Refactor old code to `FizzBuzz.compile`, to pass old tests and new test.

```
val compile: Compiler = {
  case Config((d1, w1), (d2, w2)) =>
    // Precompute, hence "compiler".
    val w = w1 + w2
    // Return an Evaluator.
    { i =>
      (i % d1 == 0, i % d2 == 0) match {
        case (true,  false) => w1
        case (false, true)  => w2
        case (true,  true)  => w
        case (false, false) => i.toString
      }
    }
}
```

Generalizing to more than two divisors

Client wants `FizzBuzzPop`!

- Given three divisors (such as 3, 5, 7).
- Given three words (such as `"Fizz"`, `"Buzz"`, `"Pop"`).
- Compile to evaluator that given an integer prints:
  - either a string combining a subset of the three words, or
  - a numerical string if the integer is not a multiple of any of the three divisors
- Example: `21` should output `"FizzPop"`.

Thought-driven development

Software development is not primarily about coding, but thinking.

- Deep fact: solving a more general problem is often easier than solving the specific problem.
- There are four important numbers in the Universe:

0	emptiness
1	existence
2	other (relationship)
many	community

More features means more tests

Write new tests for new `Defaults.fizzBuzzPopper`:

```
def is = s2"""
${Defaults.fizzBuzzPopper(2) ==== "2"}
${Defaults.fizzBuzzPopper(21) ==== "FizzPop"}
${Defaults.fizzBuzzPopper(9) ==== "Fizz"}
${Defaults.fizzBuzzPopper(7) ==== "Pop"}
${Defaults.fizzBuzzPopper(35) ==== "BuzzPop"}
"""
```

Change configuration: to `Seq` of pairs, instead of just two:

```
val fizzBuzzPopperConfig: Config =
  Config(Seq(
    3 -> "Fizz", 5 -> "Buzz", 7 -> "Pop"
  ))
val fizzBuzzPopper: Evaluator =
  FizzBuzz.compile(fizzBuzzPopperConfig)
```

More tests means more (or changed) types

```
[error] ...Defaults.scala:29: not enough arguments for
  method apply:
  (pair1: (Int, String), pair2: (Int, String))
  com.franklinchen.FizzBuzz.Config in object Config
[error] Unspecified value parameter pair2.
[error]     Config(Seq(
[error]           ^
```

Change type `Config` to allow a sequence of pairs:

```scala
case class Config(pairs: Seq[(Int, String)]) {
  pairs.foreach(validatePair)
}
```

Note how our iterative development process promotes reuse (here, of validation logic).

Fix remaining type errors

Refactoring reveals need to implement case of more than two divisors.

```scala
val compile: Compiler = {
  case Config(Seq((d1, w1), (d2, w2))) =>
    val w = w1 + w2

    { i =>
      (i % d1 == 0, i % d2 == 0) match {
        case (true,  false) => w1
        case (false, true)  => w2
        case (true,  true)  => w
        case (false, false) => i.toString
      }
    }
  case _ => // TODO handle more than 2
    { i => ??? }
}
```

General observations

- Return a sum of a subset of the configured words, if there is any divisor match.
- If there is no divisor match, return the numerical string.

More computation means more types

Compile each divisor to a "rule" that awaits input.

```
type Rule = Int => String

val buildRule: ((Int, String)) => Rule = {
  case (n, word) => { i =>
    if (i % n == 0) word else ""
  }
}
```

FizzBuzz demo time!

- Two volunteers: to play role of `Rule`.
- One volunteer: to combine sub-results.

Demo explanation

- Given a sequence of rules and an integer: apply all the rules to the integer, then combine the partial results.

Assemble the types

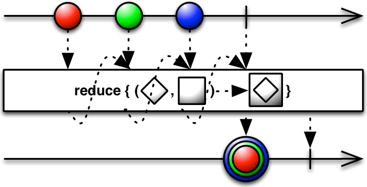
```
type Evaluator = Int    => String
type Compiler  = Config => Evaluator
type Rule      = Int    => String

val compile: Compiler = { case Config(pairs) =>
  val rules: Seq[Rule] = pairs.map(buildRule) // compile

  // Return an Evaluator.
  { i =>
    val words: Seq[String] = rules.map { rule => rule(i) }
    val combined: String = words.reduce { (x, y) => x + y }
    if (combined == "") i.toString else combined
  }
}
```

A note on `reduce`

For any value of type `Seq[A]`, `reduce: ((A, A) => B) => B`.



Example: for `Seq[String]`, reduction with string concatenation `+` returns the concatenation of all the strings in the sequence.

Test failure: coarse types again

```
nfo]   x Arbitrary pair of divisors: divisible by first
rror]  A counter-example is 'Config(List((8,), (32,)))'
(after 0 try)
rror]  A counter-example is '32405464'
(after 0 try - shrinked ('1150076488' -> '32405464'))
rror]  '32405464' is not equal to ''
(FizzBuzzSpec.scala:71)
```

Demo time!

- Configuration: `Seq(3 -> "", 5 -> "Buzz")`
- Input: `2`
- Output: should be `""`
- Output was: `"2"`

Property-based testing rescued us again!

Be honest: would you have caught this bug manually?

- I didn't.
- I never wrote `FizzBuzzPop` examples testing empty strings.
- Property-based testing reveals unexpected corner cases.
  - (Empty "fizz" and "buzz" word strings).

An empty string is not equivalent to no string

Presence of something "empty" is not equivalent to no thing.

Sending someone an empty email versus not sending any email.

Many programming languages get this wrong.

Option[A] type

Option[A] is one of two possibilities:

- None
- Some(a) wraps a value a of type A.

For example, Some("") is not the same as None.

```
val fizzFor3     = Some("") // multiple of 3
val buzzFor3     = None     // not multiple of 5
val fizzbuzzFor3 = Some("") // fizzed ""

val fizzFor2     = None     // not multiple of 3
val buzzFor2     = None     // not multiple of 5
val fizzbuzzFor2 = None     // not multiple of any
```

Cleaning up the types

```
// was: type Rule = Int => String
type Rule = Int => Option[String]
```

Useful type errors:

```
und    : String
quired: Option[String]
     word
     ^
und    : String("")
quired: Option[String]
     ""
     ^
und    : Seq[Option[String]]
quired: Seq[String]
     val words: Seq[String] = rules map { rule => rule(i) }
                                    ^
```

Fix the type errors: our rule builder

```
type Rule = Int => Option[String]

val buildRule: ((Int, String)) => Rule = {
  case (n, word) => { i =>
    (i % n == 0).option(word)
  }
}
```

Demo time!

- (Instructions: circle what you write to wrap it with `Some`)
- Configuration: `Seq(3 -> "", 5 -> "Buzz")`
- Input: `2`
- Output: should be `""`

Fix the type errors: our compiler

```
val compile: Compiler = { case Config(pairs) =>
  val rules: Seq[Rule] = pairs map buildRule

  { i =>
    val wordOptions: Seq[Option[String]] =
      rules.map { rule => rule(i) }
    val combinedOption: Option[String] =
      wordOptions.reduce(addOption)
    combinedOption.getOrElse(i.toString)
  }
}
```

- We need to write: `addOption`
- Scala standard library provides: `getOrElse`

“Addition” for Option[String]

```scala
def addOption(a1: Option[String], a2: Option[String]):
    Option[String] = (a1, a2) match {
  case (Some(s1), None)     => Some(s1)
  case (None,     Some(s2)) => Some(s2)
  case (Some(s1), Some(s2)) => Some(s1 + s2)
  case (None,     None)     => None
}
```

Getting `A` back out of `Option[A]`

Do not lose information!

`getOrElse` inspects the
and either

- returns the value `v` inside a `Some(v)`,
- or else returns the specific default value.

Swift has two option types

Swift calls them "optionals".

Normal optional type

- `A?` is a type for each type `A`.
- Must unwrap explicitly.

Implicit unwrapped optional type

- `A!` is a type for each type `A`.
- Unfortunate type hole:

  > *If you try to access an implicitly unwrapped optional when it does not contain a value, you will trigger a runtime error.*

The same thing, in Swift

```
func addOption(a1: String?, a2: String?) -> String? = {
  switch (a1, a2) {
  case (let .Some(s1), .None):           return .Some(s1)
  case (.None, let .Some(s2)):           return .Some(s2)
  case (let .Some(s1), let .Some(s2)): return .Some(s1+s2)
  case (.None, .None):                   return .None
  }
}
```

Transform information; don't destroy it

Did you notice? Our new code no longer uses `if`.

Bug cause: destroying information, using `if`

- Building a rule: `if (i % n == 0) word else ""`
- Obtaining a final string answer:
  `if (combined == "") i.toString else combined`

Transforming information

- To `Option[String]`: `(i % n == 0).option(word)`
- To `String`: `combinedOption.getOrElse(i.toString)`

Type-directed design tip

We could have saved trouble up front, by using precise types.

- Avoid `if`, when possible.
- Avoid `String` (but required at I/O boundaries of program).

Bonus: the final code in Swift

```swift
typealias Evaluator = Int -> String
typealias Config = (Int, String)[]
typealias Compiler = Config -> Evaluator
typealias Rule = Int -> String?

let buildRule: ((Int, String)) -> Rule = { n, word in
  { i in (i % n == 0) ? word : nil } }
}

let compile: Compiler = { pairs in
  let rules: Rule[] = pairs.map(buildRule)
  return { i in
    let wordOptions = rules.map { rule in rule(i) }
    let combinedOption = wordOptions.reduce(nil, addOption)
    if let combined = combinedOption { return combined }
                                     else { return String(i) }
  }
}
```

Parallelism

- Use of map: parallelizable; there are high-performance parallel collections for Scala.
- Use of reduce: parallelizable because of the monoid property:

`Option[String]` is a Monoid

- There is an identity element (`None`).
- There is a binary associative operator (`addOption`).
- Fantastically important in practice!

Demo time!

- Configuration:
  `Seq(3 -> "Fizz", 5 -> "Buzz", 7 -> "Pop", 2 -> "Boom")`
- Input: `42`
- Output: `"FizzPopBoom"`

Final parallelized code

```scala
val parallelCompile: Compiler = { case Config(pairs) =>
  val rules = pairs.toArray
    toArray.
    toPar.
    map(buildRule)

  { i: Int => rules.
    map { rule => rule(i) }.
    reduce(addOption).
    getOrElse(i.toString)
  }
}
```

Coding style tip

This level of conciseness is not always best: maybe too "clever"?

Parallelism for Swift?

I expect people to develop libraries for parallelism in Swift.

Parallelism summary

We discovered a theoretical speedup for generalized `FizzBuzz`:

- Sequential: $O(n)$
- Parallel: $O(\log n)$ (given $\log n$ processors, and omitting some technical subtleties)

Also, driver outer loop can be sped up:

- Sequential loop on 1 to m: $O(m)$
- Parallel loop: $O(1)$ (given m processors)

Future work

- Asynchronous
- Real-time
- Interactive

Conclusion

- Tests are great.
- Types are great.
- Tests and types work hand in hand, driving design and program evolution.
- Modern typed languages such as Scala promote fun, correct programming!
- It's a great time to be learning and using a modern typed language: Apple ditched Objective C for Swift.

Code, slides, article

- Go to https://github.com/franklinchen/talk-on-type-directed-tdd-using-fizzbuzz
- The article has more detail omitted in the presentation.
- The hyperlinks in all provided PDFs are clickable.
- The Swift code: https://github.com/franklinchen/fizzbuzz-swift

Some free online courses on modern typed functional programming

- Using Scala: Functional Programming Principles in Scala on Coursera, taught by Martin Odersky (inventor of Scala)
- Using Haskell: Introduction to Functional Programming on EdX, taught by Erik Meijer (Haskell hero)