Away with the types!

Dave Gurnell, @davegurnell

underscore

Working with
partial type information

Concrete

vs

Generic

Types

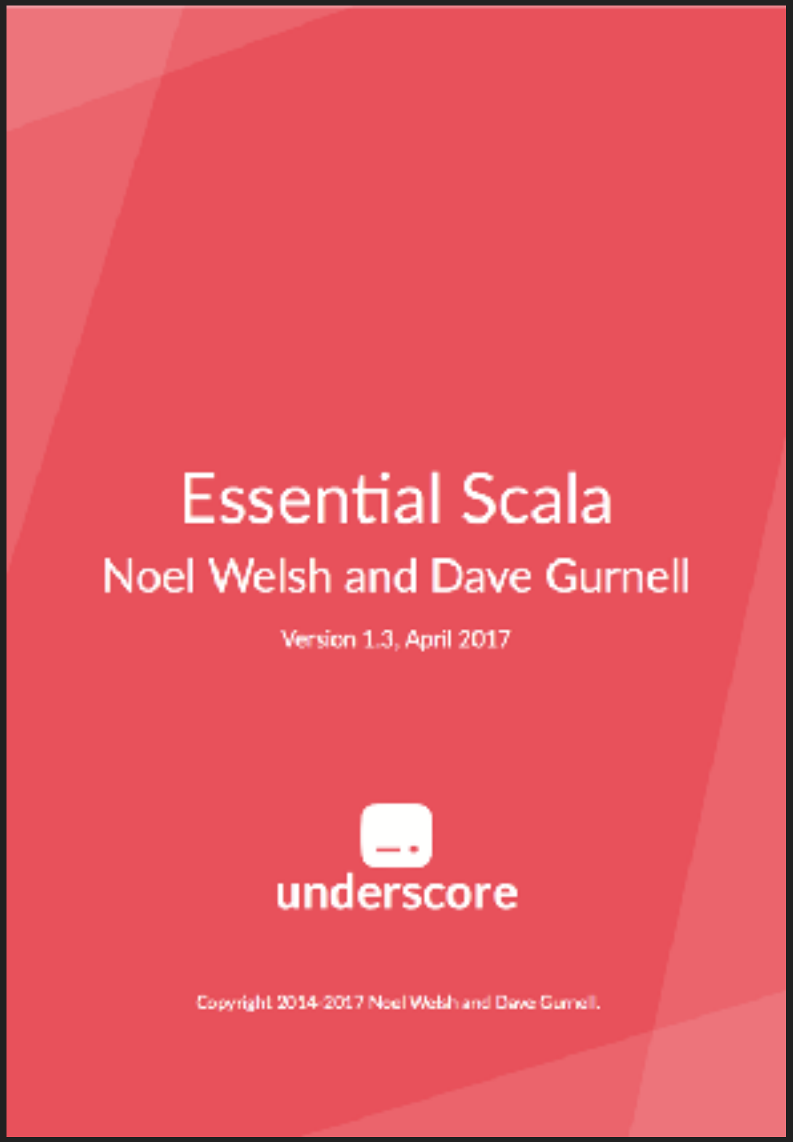
vs

Schemas

Error handling monads

Type classes

Interpreter pattern



Essential Scala

Noel Welsh and Dave Gurnell

Version 1.3, April 2017

underscore

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underscore.io/books/
essential-scala

Scala with Cats

Noel Welsh and Dave Gurnell

underscore

underscore.io/books/
scala-with-cats

The Type Astronaut's

Guide to Shapeless

Dave Gurnell

foreword by Miles Sabin

underscore

underscore.io/books/
shapeless-guide

https://github.com/davegurnell/
away-with-the-types

What are static types?

Sets of facts
we know about a program
without running it

A shape is always
a rectangle or a circle

```scala
sealed trait Shape

final case class Rectangle(
  width: Double,
  height: Double,
  color: Color) extends Shape

final case class Circle(
  radius: Double,
  color: Color) extends Shape
```

A rectangle
has three
fields

A circle has two

They let the compiler check our code

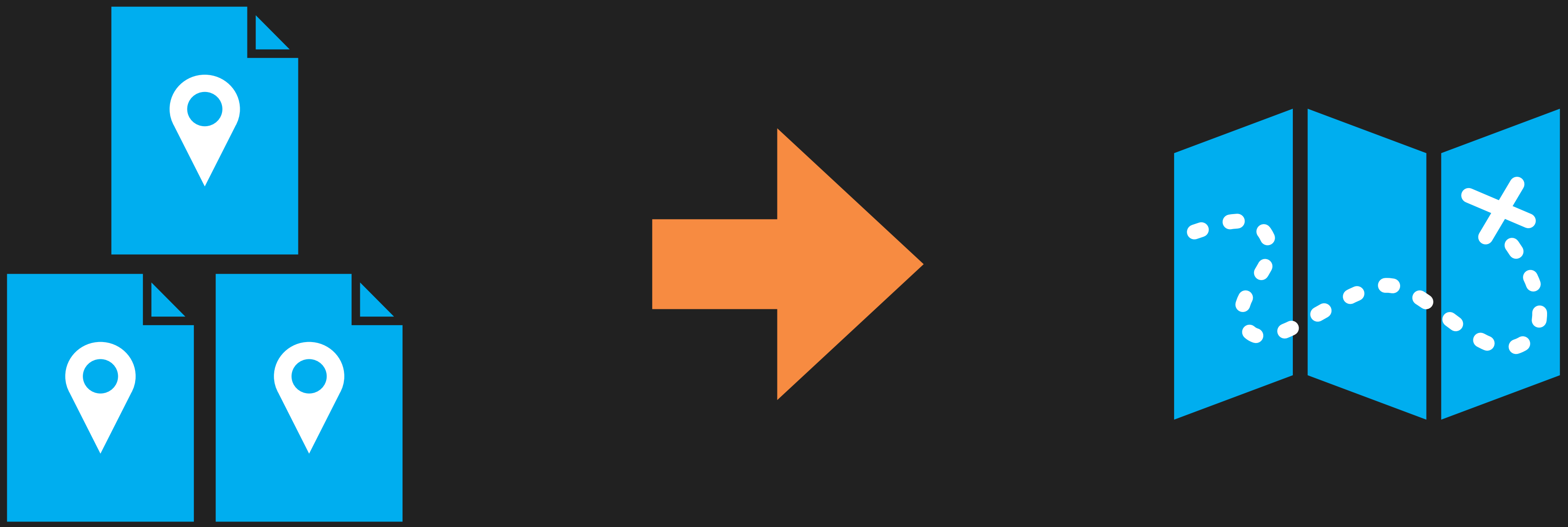
They help the compiler
write code for us
(e.g. type classes)

What if we don’t know
the types at compile time?

I HAVE SEEN THE END
NO ONE WAS SPARED, NOT EVEN THE CHILDREN

How did we get into this situation?

cartographer



Algebraic data type

Product types
“ANDs” of other types

Sum types
“ORs” of other types

```scala
sealed trait Survey

final case class WaterQuality(
  temperature: Int,
  ph: Double,
  // ...
) extends Survey

final case class Litter(
  itemCollected: String,
  quantity: Int,
  // ...
) extends Survey
```

Habitat

Amenity

Water quality

Litter cleanups

Invasive flora/fauna

Vegetation

Camera trapping

Animal footprint

Radiotracking

Spotlighting

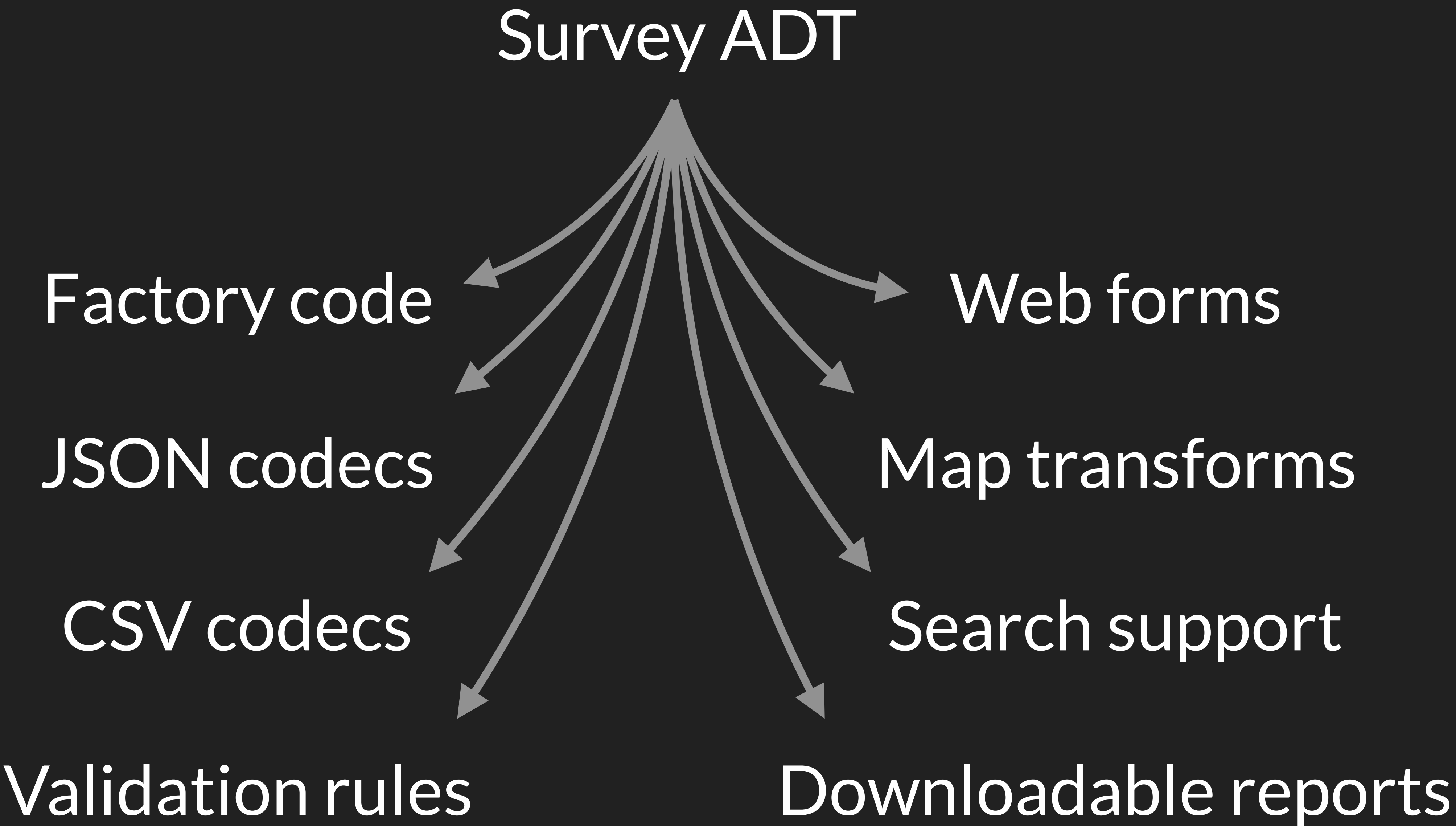
```scala
sealed trait Survey { ... }
final case class CanalEnvironmentSurvey(...) extends Survey
final case class Ecostatus(...) extends Survey
final case class LutonLeaJuniorRiverWarden(...) extends Survey
final case class LutonLeaRiverlution(...) extends Survey
final case class MorphSurvey(...) extends Survey
final case class Thames21BadgedGroupEvent(...) extends Survey
final case class Thames21GreenWallModule(...) extends Survey
final case class Thames21InvasiveSpecies(...) extends Survey
final case class Thames21Litter(...) extends Survey
final case class Thames21RapidAppraisal(...) extends Survey
final case class Thames21Vegetation(...) extends Survey
final case class Thames21WaterQuality(...) extends Survey
final case class RoyalParksCameraTrapping(...) extends Survey
final case class RoyalParksFootprintTunnel(...) extends Survey
final case class RoyalParksRadiotracking(...) extends Survey
final case class RoyalParksSpotlighting(...) extends Survey
final case class UrbanRiverSurvey(...) extends Survey
final case class WrtWestcountryCsi(...) extends Survey
final case class WrtUpstreamThinking(...) extends Survey
```

```
case class UrbanRiverSurvey(
  secondSurveyor: Option[Surveyor],
  surveyDetails: UrsSurveyDetails,
  siteInformation: UrsSiteInformation,
  stretchEngineering: UrsStretchEngineering,
  channelDimensions: UrsChannelDimensions,
  spotChecks: List[UrsSpotCheck],
  sweepUp: UrsSweepUp,
  bankProfileAndProtection: UrsBankProfileAndProtection,
  channelDynamics: UrsChannelDynamics,
  artificialInfluences: UrsArtificialInfluences,
  extentOfPollution: UrsExtentOfPollution,
  habitatFeatures: UrsHabitatFeatures,
  specialFeatures: UrsSpecialFeatures,
  ecologicalCharacteristics: UrsEcologicalCharacteristics
) extends Survey

case class UrsSurveyDetails(
  wfdWaterBodyId: Option[String],
  riverName: Option[String],
  stretchName: Option[String],
  stretchCode: Option[String],
  neasProjectName: Option[String],
  neasProjectCode: Option[String],
  neasSurveyType: Option[UrsNeasSurveyType]
)

case class UrsSiteInformation(
  stretchLength: Option[Int],
  upstreamLocation: Option[Wgs84],
  downstreamLocation: Option[Wgs84],
  distanceFromSource: Option[Int],
  slope: Option[Double],
  solidGeologyCode: Option[String],
  driftGeologyCode: Option[String],
  photographs: UploadSubfolder,
  surveyBank: Option[UrsSurveyBank],
  surveyStart: Option[UrsSurveyStart],
  photoCredit: Option[String],
  photoLicense: Option[String],
  photoReferences: Option[String],
  bedVisible: Boolean,
  adverseConditions: Boolean,
  adverseConditionsSummary: Option[String],
)

case class UrsStretchEngineering(
  planform: Option[UrsPlanform],
  crossProfile: Option[UrsCrossProfile],
  reinforcementLevel: Option[UrsReinforcementLevel],
)
```

```
case class UrsChannelDimensions(
  onceOnlyDistanceFromUpstream: Option[Int],
  onceOnlyLocation: Option[Wgs84],
  onceOnlyAtRiffleOrRun: Boolean,
  onceOnlySpotCheck: Option[Int],
  channelBankfullWidth: Option[Double],
  channelWaterWidth: Option[Double],
  channelWaterDepth: Option[Double],
  leftBankTopHeight: Option[Double],
  leftEmbankedHeight: Option[Double],
  rightBankTopHeight: Option[Double],
  rightEmbankedHeight: Option[Double],
)

case class UrsSpotCheck(
  number: Int,
  location: Option[Wgs84],
  leftBankMaterial: Option[UrsBankMaterial],
  rightBankMaterial: Option[UrsBankMaterial],
  leftBankProtection: Option[UrsBankProtection],
  rightBankProtection: Option[UrsBankProtection],
  leftBankMarginalFeature: Option[UrsMarginalFeature],
  rightBankMarginalFeature: Option[UrsMarginalFeature],
  channelSubstrate: Option[UrsChannelSubstrate],
  flowType: Option[UrsFlowType],
  channelFeature: Option[UrsChannelFeature],
  leftBankLandUse: Option[UrsLandUse],
  rightBankLandUse: Option[UrsLandUse],
  leftBankTopStructure: Option[UrsBankStructure],
  rightBankTopStructure: Option[UrsBankStructure],
  leftBankFaceStructure: Option[UrsBankStructure],
  rightBankFaceStructure: Option[UrsBankStructure],
  vegetation: PercentageDistribution[UrsVegetation]
)

object UrsSpotCheck {
  def default: List[UrsSpotCheck] =
    (1 to 10).map(num => UrsSpotCheck(number = num)).toList
}

case class UrsSweepUp(
  sweepUpChannelSubstrate: Option[UrsChannelSubstrate],
  sweepUpChannelVegetation: PercentageDistribution[UrsVegetation],
  chokedWithMacrophytes: YesNoUnknown,
  macrophyteNotes: Option[String],
)
```

```
case class UrsBankProfileAndProtection(
  bankProfileAndProtectionAmalgamated: Boolean,
  leftBankNaturalProfile: PercentageDistribution[UrsNaturalBankProfile],
  rightBankNaturalProfile: PercentageDistribution[UrsNaturalBankProfile],
  leftBankArtificialReinforcement: PercentageDistribution[UrsArtificialBankReinforcement],
  rightBankArtificialReinforcement: PercentageDistribution[UrsArtificialBankReinforcement],
  leftBankArtificialProfile: PercentageDistribution[UrsArtificialBankProfile],
  rightBankArtificialProfile: PercentageDistribution[UrsArtificialBankProfile],
  leftBankProtection: PercentageDistribution[UrsBankProtection],
  rightBankProtection: PercentageDistribution[UrsBankProtection]
)

case class UrsChannelDynamics(
  channelDynamics: Map[UrsChannelDynamicsCategory, UrsChannelDynamicsExtent],
  channelDynamicsFeatures: Map[UrsChannelDynamicsFeature, UrsApe]
)

case class UrsArtificialInfluences(
  artificialFeatures: Counts[UrsArtificialFeature],
  artificialFeaturesNotes: Option[String],
  bridgeTypes: Counts[UrsBridgeType],
  nuisanceSpecies: Map[UrsNuisanceSpecies, UrsSpeciesFrequency],
  otherNuisanceSpecies: Option[String],
  recentManagement: Map[UrsManagementFeature, UrsApe],
  recentManagementNotes: Option[String],
  otherNotes: Option[String],
)

case class UrsExtentOfPollution(
  pollutionIndicators: Map[UrsPollutionIndicator, UrsApe],
  pollutionSources: Counts[UrsPollutionSource],
  waterClarity: Option[UrsWaterClarity],
  waterClarityNotes: Option[String],
)

case class UrsHabitatFeatures(
  countedHabitatFeatures: Counts[UrsCountedHabitatFeature],
  percentageHabitatFeatures: PercentageDistribution[UrsPercentageHabitatFeature]
)

case class UrsSpecialFeatures(
  specialFeatures: Map[UrsSpecialFeature, UrsApe],
  treeFeatures: Map[UrsTreeFeature, UrsApe],
  leftBankTreeDistribution: Option[UrsTreeDistribution],
  rightBankTreeDistribution: Option[UrsTreeDistribution],
  photographs: UploadSubfolder
)

case class UrsEcologicalCharacteristics(
  ecologicalCharacteristics: Map[UrsEcologicalCharacteristic, Boolean],
  ecologicalCharacteristicsNotes: Option[String],
  observedProtectedSpecies: Map[UrsProtectedSpecies, Boolean],
  physicalSignsOfProtectedSpecies: Map[UrsProtectedSpecies, Boolean],
  suitableHabitatForProtectedSpecies: Map[UrsProtectedSpecies, Boolean]
)
```

Survey ADT



Survey ADT

Factory code

JSON codecs

CSV codecs

Validation rules

Web forms

Map transforms

Search support

Downloadable reports

User-defined surveys (like *Survey Monkey*)

Users exist
at run time!

User-defined surveys
(like *Survey Monkey*)

How do we…

Edit types at runtime?

Store types in a database?

Send types over the wire?

Still manage to write working Scala?

We have to change representations

Representations

```scala
case class WaterQuality(
  location    : Location,
  timestamp   : ZonedDateTime,
  river       : String,
  temperature : Double,
  ph          : Option[Double],
  turbidity   : Turbidity)
```

```scala
case class Location(
  lat: Double,
  lng: Double)

sealed trait Turbidity
case class QualitativeTurbidity(description: String)
  extends Turbidity
case class QuantitativeTurbidity(value: Int)
  extends Turbidity

case class WaterQuality(
  location    : Location,
  timestamp   : ZonedDateTime,
  river       : String,
  temperature : Double,
  ph          : Option[Double],
  turbidity   : Turbidity)
```

Concrete ⇒ Generic

“Survey” ⇒ “Data”

```scala
sealed trait Data

case class BooleanData(value: Boolean) extends Data
case class IntData(value: Int) extends Data
case class DoubleData(value: Double) extends Data
case class StringData(value: String) extends Data
case class TimestampData(value: DateTime) extends Data
case object NullData extends Data

case class ListData(values: List[Data]) extends Data

case class ProductData(values: Map[String, Data])
  extends Data
case class SumData(tpe: String, value: Data)
  extends Data
```

```scala
sealed trait Data

case class BooleanData(value: Boolean) extends Data
case class IntData(value: Int) extends Data
case class DoubleData(value: Double) extends Data
case class StringData(value: String) extends Data
case class TimestampData(value: DateTime) extends Data
case object NullData extends Data

case class ListData(values: List[Data]) extends Data

case class ProductData(values: Map[String, Data])
  extends Data
case class SumData(tpe: String, value: Data)
  extends Data
```

Value-level encoding of ADTs

```scala
val location: Location =
  Location(
    lat = 52.0,
    lng = 0.0)

val turbidity: Turbidity =
  QualitativeTurbidity(
    description = "Cloudy")

val survey: WaterQuality =
  WaterQuality(
    location    = location,
    timestamp   = ZonedDateTime.now,
    river       = Some("Thames"),
    temperature = Some(10.0),
    ph          = None,
    turbidity   = turbidity)
```

```
val location = ProductData(ListMap(
  "lat" -> DoubleData(52.0),
  "lng" -> DoubleData(0.0)))

val turbidity = SumData(
  "QualitativeTurbidity",
  ProductData(ListMap(
    "description" -> StringData("Cloudy")
  )))

val survey = ProductData(ListMap(
  "location"    -> location,
  "timestamp"   -> TimestampData(ZonedDateTime.now),
  "river"       -> StringData("Thames"),
  "temperature" -> DoubleData(10.0),
  "ph"          -> NullData,
  "turbidity"   -> turbidity))
```

We still have types

But we’ve lost
a lot of type information

```
val survey: WaterQuality =
  // ...

val temp: Double =
  survey.temperature
```

```scala
val survey: Data =
  // ...

val temperature: Option[Data] =
  survey match {
    case ProductData(fields) =>
      fields.get("temperature")

    case _ =>
      None
  }
```

```scala
val survey: Data =
  // ...

val temperature: Option[Double] =
  survey match {
    case ProductData(fields) =>
      fields.get("temperature") match {
        case DoubleData(temp) =>
          Some(temp)

        case _ =>
          None
      }

    case _ =>
      None
  }
```

```scala
val survey: WaterQuality =
  // ...

val latitude: Double =
  survey.location.lat
```

WHAT HAS BEEN SEEN...
Cannot be un-seen.

Lots of operations can fail

How do we cope with failure?

We use a monad!

Represent errors using Either

Accessing fields

```
sealed trait Data {

  def get(field: String): Either[String, Data] =
    ???

}
```

```scala
sealed trait Data {

  def get(field: String): Either[String, Data] =
    this match {
      case ProductData(fields) =>
        fields
          .get(field)
          .toRight(s"field not found: $field")

      case SumData(_, data) =>
        data.get(field)

      case _ =>
        Left(s"field not found: $field")
    }

}
```

```
val latitude: Either[String, Double] =
  for {
    locData <- survey.get("location")
    latData <- locData.get("lat")
    lat     <- // interpret as a Double
 } yield lat
```

Reclaiming type information

Scala types ⇔ Data values

Data ⇒ Scala

Type classes

```
trait ToData[A] {
  def apply(value: A): Data
}
```

```scala
trait ToData[A] {
  def apply(value: A): Data
}

object ToData {

  implicit val booleanToData: ToData[Boolean] =
    new ToData[Boolean] {
      def apply(value: Boolean): Data =
        BooleanData(value)
    }

  implicit val intToData: ToData[Int] =
    new ToData[Int] {
      def apply(value: Int): Data =
        IntData(value)
    }

}
```

```scala
implicit class ToDataOps[A](value: A) {

  def toData(implicit toData: ToData[A]): Data =
    toData(value)

}
```

```
123.toData
```

```
new ToDataOps(123).toData
new ToDataOps(123).toData(intToData)
```

```
123.toData
// IntData(123)
```

```
List(1, 2, 3).toData
// ListData(List(IntData(1), IntData(2), IntData(3)))
```

```
waterQualitySurvey.toData
```

```
implicit val wqToData: ToData[WaterQuality] =
  new ToData[WaterQuality] {
    def apply(wq: WaterQuality): Data =
      ProductData(ListMap(
        "location"    -> wq.location.toData,
        "timestamp"   -> wq.timestamp.toData,
        "river"       -> wq.river.toData,
        "temperature" -> wq.temperature.toData,
        "ph"          -> wq.ph.toData,
        "turbidity"   -> wq.turbidity.toData
      ))
  }
```

Data ⇒ Scala

```
trait FromData[A] {
  def apply(data: Data): Either[String, A]
}
```

```
sealed trait Data {

  def as[A](implicit from: FromData[A]): Either[String, A] =
    from(this)

}
```

```
val latitude: Either[String, Double] =
  for {
    locData <- survey.get("location")
    latData <- locData.get("lat")
    lat     <- latData.as[Double]
 } yield lat
```

```
sealed trait Data {

 def getAs[A](fields: String *)
        (implicit from: FromData[A]): Either[String, A] =
    ???

}
```

```
val latitude: Either[String, Double] =
  survey.getAs[Double]("location", "lat")
```

JSON Codecs

```scala
import io.circe._
import io.circe.syntax._

val survey: WaterQuality =
  // ...

val surveyJson: Json =
  survey.asJson

val surveyCopy: Decoder.Result[WaterQuality] =
  surveyJson.as[WaterQuality]
```

```
import io.circe._
import io.circe.syntax._

val survey: WaterQuality =
  // ...

val surveyJson: Json =
  survey.asJson(Encoder[WaterQuality])

val surveyCopy: Decoder.Result[WaterQuality] =
  surveyJson.as[WaterQuality](Decoder[WaterQuality])
```

```scala
import io.circe._
import io.circe.syntax._

val survey: Data =
  // ...

val surveyJson: Json =
  survey.asJson(Encoder[Data])

val surveyCopy: Decoder.Result[Data] =
  surveyJson.as[Data](Decoder[Data])
```

```
val surveyJson: Json =
  survey.asJson
// {
//   "location"    : { "lat": 52.0, "lng": 0.0 },
//   "timestamp"   : "2017-12-10T10:15:00Z",
//   "river"       : "Thames",
//   "temperature" : 10.0,
//   "ph"          : null,
//   "turbidity"   : { "QualitativeTurbidity": {
//                       "description": "Cloudy"
//                     }}
//   }
// }

val surveyCopy: Decoder.Result[Data] =
  surveyJson.as[Data]
```

Discarding information

```
val surveyJson: Json =
  survey.asJson
// {
//   "location"    : { "lat": 52.0, "lng": 0.0 },
//   "timestamp"   : "2017-12-10T10:15:00Z",
//   "river"       : "Thames",
//   "temperature" : 10.0,
//   "ph"          : null,
//   "turbidity"   : { "QualitativeTurbidity": {
//                       "description": "Cloudy"
//                     }}
//   }
// }

val surveyCopy: Decoder.Result[Data] =
  surveyJson.as[Data]
```

Gaining information

```
val surveyJson: Json =
  survey.asJson
// {
//   "location"    : { "lat": 52.0, "lng": 0.0 },
//   "timestamp"   : "2017-12-10T10:15:00Z",
//   "river"       : "Thames",
//   "temperature" : 10.0,
//   "ph"          : null,
//   "turbidity"   : { "QualitativeTurbidity": {
//                      "description": "Cloudy"
//                   }}
//   }
// }
```

Product or Sum?

```
val surveyCopy: Decoder.Result[Data] =
  surveyJson.as[Data]
```

We need the information from WaterQuality

But we can’t define WaterQuality
at compile time!

Types ⇒ Schemas

```scala
sealed trait Schema

case object BooleanSchema extends Schema
case object IntSchema extends Schema
case object DoubleSchema extends Schema
case object StringSchema extends Schema
case object TimestampSchema extends Schema

case class ListSchema(child: Schema) extends Schema
case class OptionSchema(child: Schema) extends Schema

case class ProductSchema(children: ListMap[String, Schema])
  extends Schema
case class SumSchema(children: ListMap[String, Schema])
  extends Schema
```

```
sealed trait Schema

case object BooleanSchema extends Schema
case object IntSchema extends Schema
case object DoubleSchema extends Schema
case object StringSchema extends Schema
case object TimestampSchema extends Schema

case class ListSchema(child: Schema) extends Schema
case class OptionSchema(child: Schema) extends Schema

case class ProductSchema(children: ListMap[String, Schema])
  extends Schema
case class SumSchema(children: ListMap[String, Schema])
  extends Schema
```

Schema-level encoding of ADTs

```scala
case class Location(
  lat: Double,
  lng: Double)

sealed trait Turbidity
case class QualitativeTurbidity(description: String)
  extends Turbidity
case class QuantitativeTurbidity(value: Int)
  extends Turbidity

case class WaterQuality(
  location    : Location,
  timestamp   : ZonedDateTime,
  river       : String,
  temperature : Double,
  ph          : Option[Double],
  turbidity   : Turbidity)
```

```
val locationSchema = ProductSchema(ListMap(
  "lat" -> DoubleSchema,
  "lng" -> DoubleSchema))

val turbiditySchema = SumSchema(ListMap(
  "QualitativeTurbidity"  -> ProductSchema(ListMap(
    "description" -> StringSchema)),
  "QuantitativeTurbidity" -> ProductSchema(ListMap(
    "value"       -> IntSchema))))

val waterQualitySchema = ProductSchema(ListMap(
  "location"    -> locationSchema,
  "timestamp"   -> TimestampSchema,
  "river"       -> StringSchema,
  "temperature" -> DoubleSchema,
  "ph"          -> OptionSchema(DoubleSchema),
  "turbidity"   -> turbiditySchema))
```

```scala
sealed trait Schema {
  def typeCheck(data: Data): List[String] =
    ???
}
```

```scala
sealed trait Schema {
  def typeCheck(data: Data): List[String] = {
    (this, data) match {
      case (BooleanSchema, _: BooleanData)     => Nil
      case (IntSchema, _: IntData)             => Nil
      case (DoubleSchema, _: DoubleData)       => Nil
      case (StringSchema, _: StringData)       => Nil
      case (TimestampSchema, _: TimestampData) => Nil

      case (ListSchema(s), ListData(ds))       => ds.flatMap(s.typeCheck)

      case (OptionSchema(s), NullData)         => Nil
      case (OptionSchema(s), d)                => s.typeCheck(d)

      case (s: ProductSchema, d: ProductData)  => // ...
      case (s: SumSchema, d: SumData)          => // ...

      case (s, d)                              => typeError(s, d)
    }
  }
}
```

```
val waterQualitySchema: Schema =
  // ...

val slightlyIncorrectData: Data =
  // ...

waterQualitySchema.typeCheck(slightlyIncorrectData)
// List("missing field: location", ...)
```

Schemas fill in
missing information

They do it at run time,
not compile time

Back to JSON codecs

```
val surveyJson: Json =
  survey.asJson
// {
//   "location"    : { "lat": 52.0, "lng": 0.0 },
//   "timestamp"   : "2017-12-10T10:15:00Z",
//   "river"       : "Thames",
//   "temperature" : 10.0,
//   "ph"          : null,
//   "turbidity"   : { "QualitativeTurbidity": {
//                       "description": "Cloudy"
//                     }}
//   }
// }
```

Product or Sum?

```
val surveyCopy: Decoder.Result[Data] =
  surveyJson.as[Data]
```

```
val surveyJson: Json =
  survey.asJson
// {
//   "location"    : { "lat": 52.0, "lng": 0.0 },
//   "timestamp"   : "2017-12-10T10:15:00Z",
//   "river"       : "Thames",
//   "temperature" : 10.0,
//   "ph"          : null,
//   "turbidity"   : { "QualitativeTurbidity": {
//                     "description": "Cloudy"
//                   }}
//   }
// }
```

Product or Sum?

```
val surveyCopy: Decoder.Result[Data] =
  surveyJson.as(decoder(waterQualitySchema))
```

```
def decoder(schema: Schema): Decoder[Data] =
  schema match {
    case BooleanSchema    => booleanDecoder
    case IntSchema        => intDecoder
    case DoubleSchema     => doubleDecoder
    case StringSchema     => stringDecoder
    case TimestampSchema  => timestampDecoder
    case ListSchema(s)    => listDecoder(decoder(s))
    case OptionSchema(s)  => decoder(s).or(nullDecoder)
    case s: ProductSchema => productDecoder(s)
    case s: SumSchema     => sumDecoder(s)
  }
```

Validating schemas

We’re replacing types with schemas

How do we know
the schemas are correct?

Types ⇒ Tests

Scalacheck

```
import org.scalatest._
import org.scalacheck._

forAll { (value: Int) =>
  (value + 1 - 1) should be(value)
}
```

Generate random *WaterQuality* values

Convert to *Data* values using *ToData*

Type check against *waterQualitySchema*

```
import org.scalatest._
import org.scalacheck._

forAll { (survey: WaterQuality) =>
  val data: Data =
    survey.toData

  val errors: List[String] =
    waterQualitySchema.typeCheck(data)

  errors should be(Nil)
}
```

Generate random *WaterQuality* values

Convert to *Data* values using *ToData*

Convert back to *WaterQuality* using *FromData*

Check equality

Generate random *Data* values

Convert to *WaterQuality* values using *FromData*

Convert back to *Data* using *ToData*

Check equality

How do we generate random values?

```scala
import org.scalacheck._

trait Gen[A] {
  def sample: Option[A]
}

trait Arbitrary[A] {
  def arbitrary: Gen[A]
}
```

How do we generate
random *WaterQuality* values?

```scala
implicit val arbWaterQuality: Arbitrary[WaterQuality] =
  Arbitrary {
    for {
      location    <- arbitrary[Location]
      timestamp   <- arbitrary[ZonedDateTime]
      river       <- arbitrary[String]
      temperature <- arbitrary[Double]
      ph          <- arbitrary[Option[Double]]
      turbidity   <- arbitrary[Turbidity]
    } yield WaterQuality(
      location    = location,
      timestamp   = timestamp,
      river       = river,
      temperature = temperature,
      ph          = ph,
      turbidity   = turbidity
    )
  }
```

```scala
import org.scalacheck._
import org.scalacheck.ScalacheckShapeless._
```

How do we generate random *Data* values?

Schema ⇒ Gen[Data]

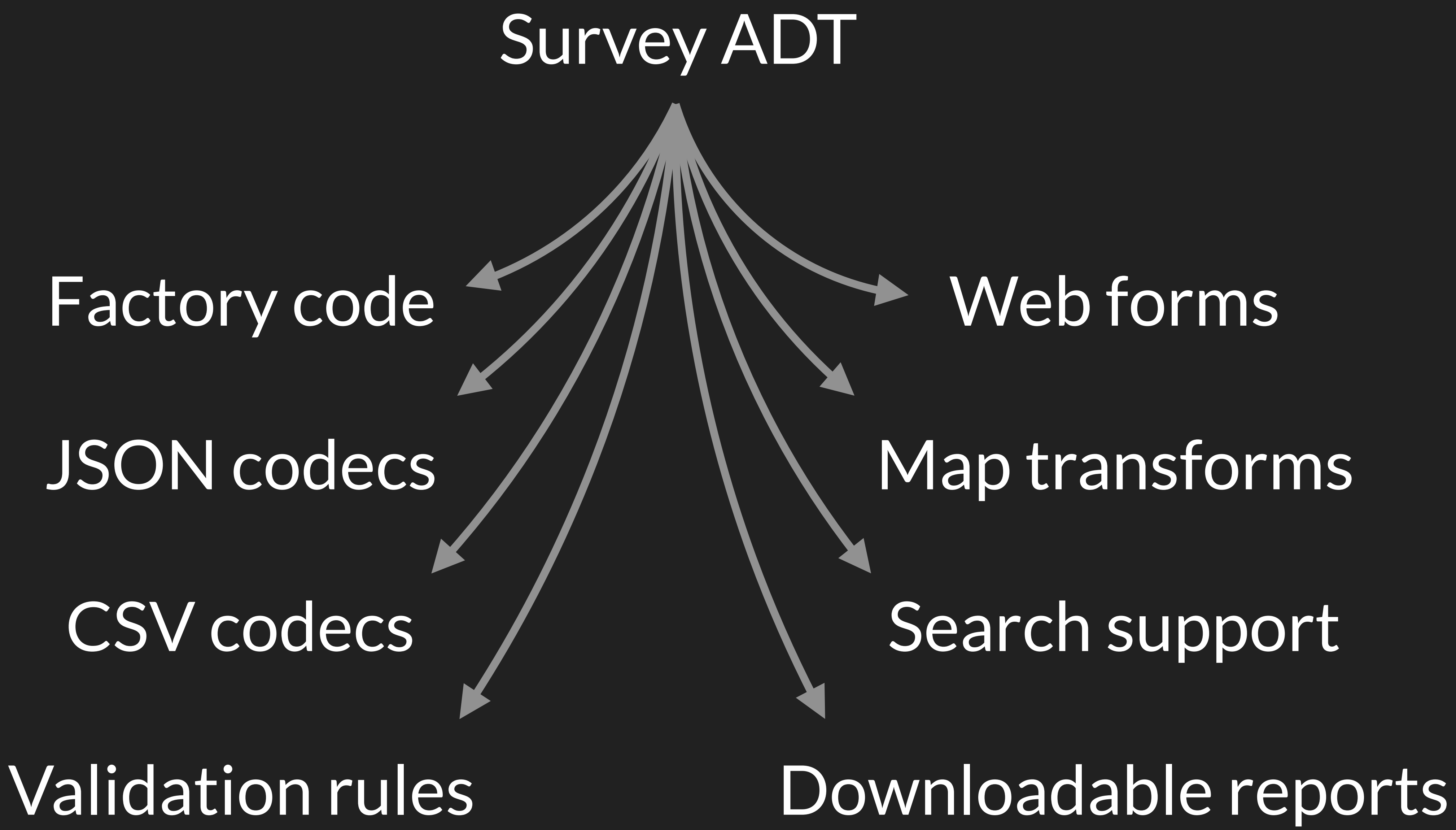
```
def genData(schema: Schema): Gen[Data] =
  schema match {
    case BooleanSchema   => arbitrary[Boolean].map(BooleanData)
    case IntSchema       => arbitrary[Int].map(IntData)
    case DoubleSchema    => arbitrary[Double].map(DoubleData)
    case StringSchema    => arbitrary[String].map(StringData)
    case TimestampSchema => arbitrary[ZonedDateTime].map(TimestampData)

    case ListSchema(child) =>
        Gen.listOf(genData(child)).map(ListData)

    case OptionSchema(child) =>
        Gen.oneOf(genNullData, genData(child))

    case ProductSchema(children) => // ...
    case SumSchema(children)     => // ...
  }
```

```scala
import org.scalatest._
import org.scalacheck._

implicit val arb: Arbitrary[Data] =
  Arbitrary(dataGen(waterQualitySchema))

forAll { (data: Data) =>
  val survey: Either[String, WaterQuality] =
    data.as[WaterQuality]

  val copy: Data =
    survey.map(_.toData)

  copy should be(Right(data))
}
```

One last complication…

We’ve replaced types with schemas

What about code that relies on those schemas?



Survey ADT

Factory code

JSON codecs

CSV codecs

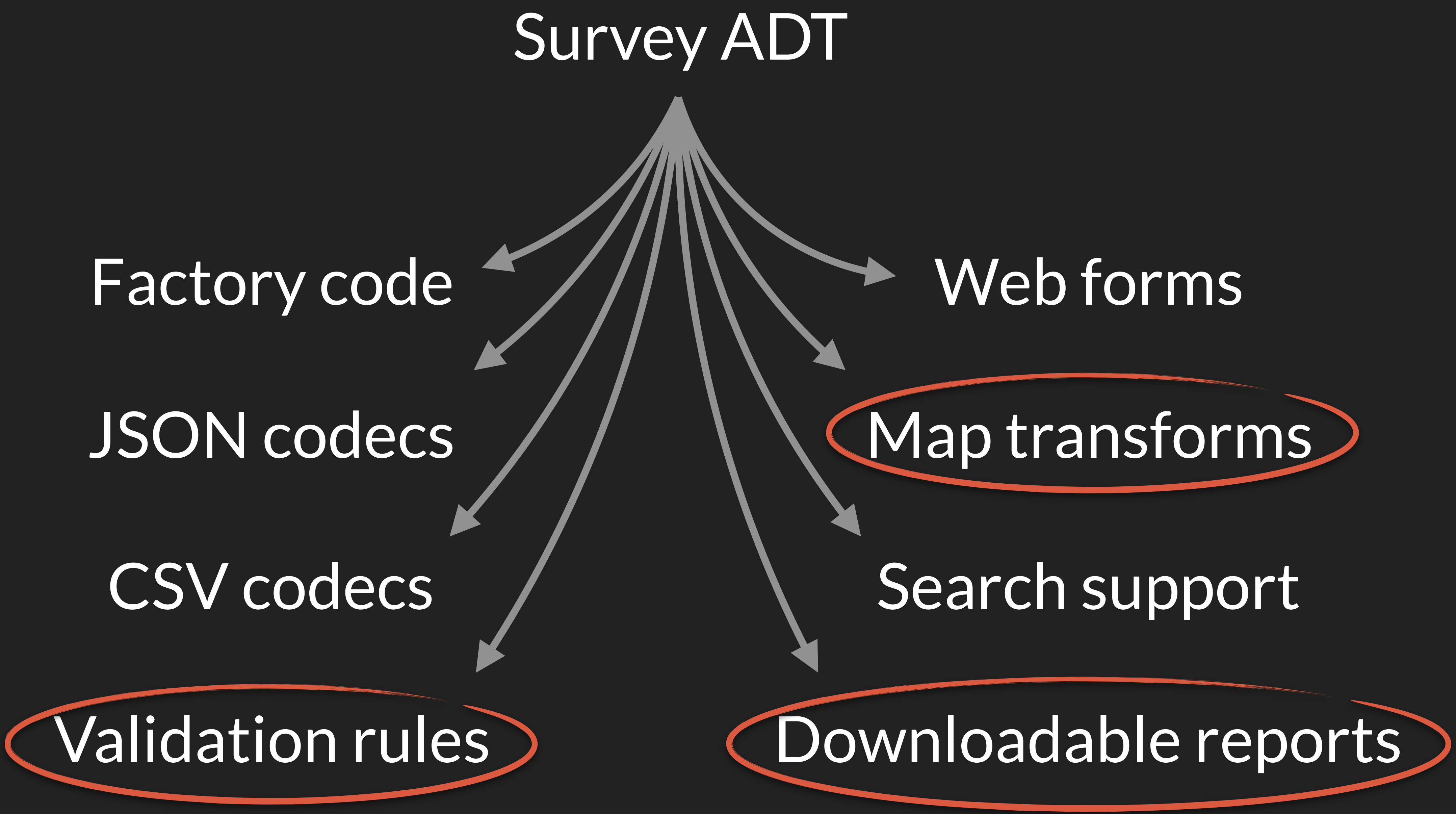
Validation rules

Web forms

Map transforms

Search support

Downloadable reports



Survey ADT

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Two options…

Either enrich the schemas…

Or represent code as values

Code ⇒ Values

Access fields in data

Apply functions to fields

Generate results of fixed Scala types
(e.g. validation rules return Boolean)

```
sealed trait Expr

final case class Const(data: Data)
  extends Expr

final case class Select(path: List[String])
  extends Expr

final case class Apply(func: String, args: List[Expr])
  extends Expr
```

```scala
def dataAt(path: String *): Expr =
  Select(path.toList)

implicit class ExprOps[A](value: A) {
  def toExpr(implicit toData: ToData[A]): Expr =
    Const(value.toData)
}
```

```scala
sealed trait Expr {
  def unary_- : Expr        = Apply("unary_-", List(this))
  def +(that: Expr): Expr   = Apply("+", List(this, that))
  def -(that: Expr): Expr   = Apply("-", List(this, that))
  def *(that: Expr): Expr   = Apply("*", List(this, that))
  def /(that: Expr): Expr   = Apply("/", List(this, that))
  def >(that: Expr): Expr   = Apply(">", List(this, that))
  def <(that: Expr): Expr   = Apply("<", List(this, that))
  def >=(that: Expr): Expr  = Apply(">=", List(this, that))
  def <=(that: Expr): Expr  = Apply("<=", List(this, that))
  def ===(that: Expr): Expr = Apply("===", List(this, that))
  def =!=(that: Expr): Expr = Apply("=!=", List(this, that))
  def unary_! : Expr        = Apply("unary_!", List(this))
  def &&(that: Expr): Expr  = Apply("&&", List(this, that))
  def ||(that: Expr): Expr  = Apply("||", List(this, that))
  def ++(that: Expr): Expr  = Apply("++", List(this, that))
  def combineAll: Expr      = Apply("combineAll", List(this))

  def getOrElse(that: Expr): Expr =
    Apply("getOrElse", List(this, that))
}
```

```
val expr: Expr =
  dataAt("temperature") >= 0.toExpr &&
  dataAt("temperature") <= 100.toExpr
```

```
val expr: Expr =
  dataAt("temperature") >= 0.toExpr &&
  dataAt("temperature") <= 100.toExpr
// Apply("&&", List(
//   Apply(">=", List(
//     Select(List("temperature")),
//     Const(IntData(0))
//   )),
//   Apply(“<=", List(
//     Select(List("temperature")),
//     Const(IntData(100))
//   ))
// ))
```

```
sealed trait Expr {
  def eval(data: Data): Either[String, Data] =
    ???

  def evalAs[A](data: Data)
      (implicit f: FromData[A]): Either[String, A] =
    eval(data).flatMap(f.apply)
}
```

```scala
val expr: Expr =
  dataAt("temperature") >= 0.toExpr &&
  dataAt("temperature") <= 100.toExpr

expr.evalAs[Boolean](data)
// Right(true)
// Right(false)
// Left("field not found: temperature”)
// etc...
```

We can also represent functions and higher order functions

```
val expr = fn { data =>
  data.ph.fold(true)(ph => ph >= 0 && ph <= 14)
}

expr.evalAs[Boolean](data)
```

```
val expr = fn { data =>
  data.ph.fold(true)(ph => ph >= 0 && ph <= 14)
}
// Func(
//   "data",
//   Apply("fold", List(
//     Select(List("data", "ph")),
//     Func("ph", ...)
//   ))
// )

expr.evalAs[Boolean](data)
```

We can serialize simple expressions

We can run them against data

We can type check them against schemas

Summary

Allowed users to edit types

Changed representations

static ⇒ dynamic

concrete ⇒ generic

Lost type information

Regained type safety with the Either monad

Regained lost information with schemas

Regained type checking with property-based tests

Created serializable data and code

But it was a lot of work

Don’t throw away your types

Further reading

https://github.com/davegurnell/
away-with-the-types

Kris Nuttycombe

Describing Data
with free applicative functors
(and more)

https://www.youtube.com/watch?v=oRLkb6mqvVM

Ionuț G. Stan

A Type Inferencer for ML
in 200 Lines of Scala

https://www.youtube.com/watch?v=H7x4THVU4BQ

15:15 today

Andrew Gustafson

Moving Away from Hope-Driven Development

16:15 today

Ben Parker

Almost Type-Safe Error Handling

16:15 today

Maria-Livia Chiorean

The Path to Generic Endpoints Using Shapeless

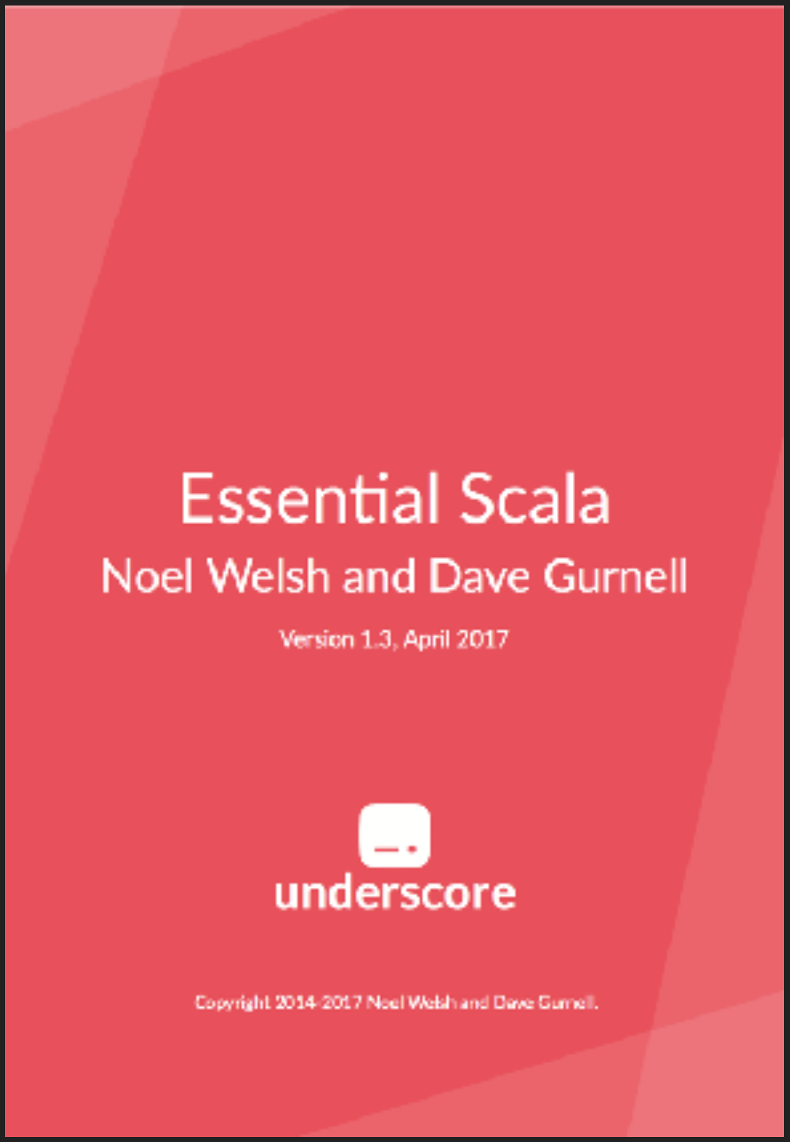
15:00 tomorrow

Dan Porter

Holophrase: Baby’s First DSL

#Scalax2gether

(Saturday 9am to 4pm)



Essential Scala

Noel Welsh and Dave Gurnell

Version 1.3, April 2017

underscore

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underscore.io/books/
essential-scala

Scala with Cats

Noel Welsh and Dave Gurnell

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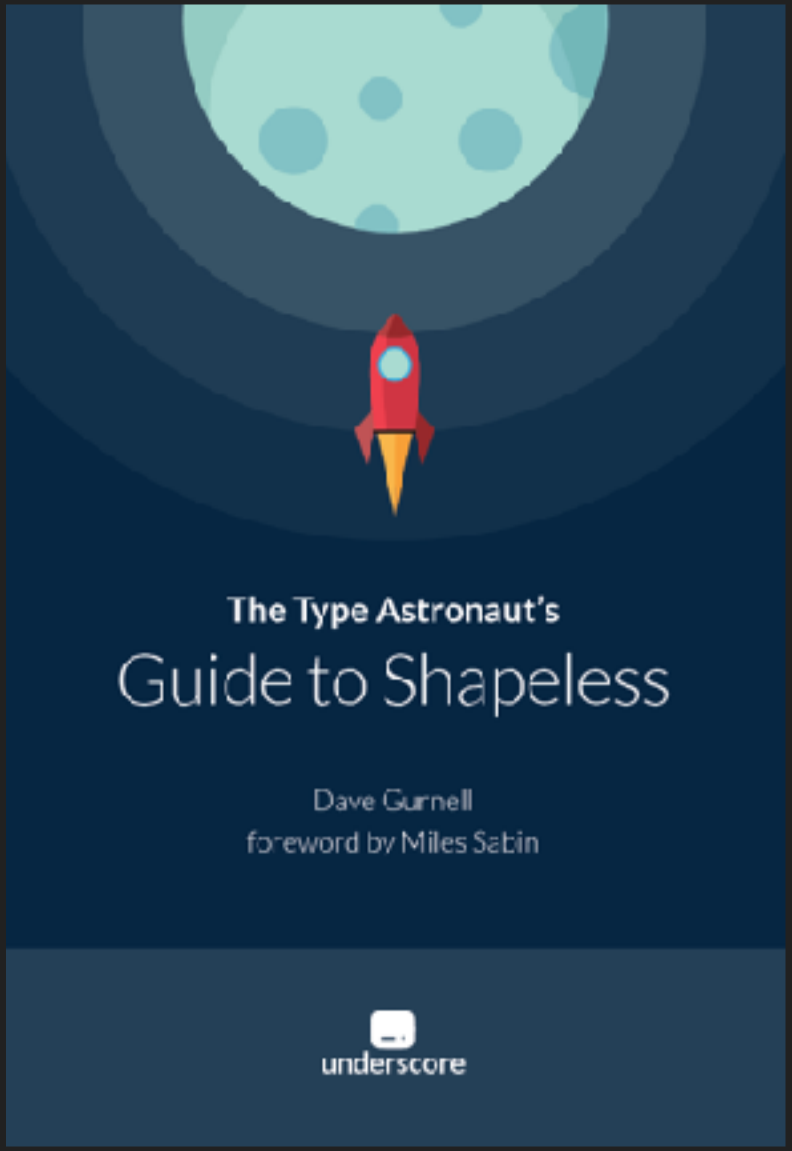
underscore.io/books/
scala-with-cats



The Type Astronaut's

Guide to Shapeless

Dave Gurnell

foreword by Miles Sabin

underscore

underscore.io/books/
shapeless-guide

Algebraic Data Types

Essential Scala, Chapter 2

flatMap and map

Essential Scala, Chapter 4

Type classes and extension methods

Essential Scala, Chapter 7

Scala with Cats, Chapters 1 and 2

Either and Validated

Scala with Cats, Chapters 4 and 6

Deriving ToData and FromData automatically

Shapeless Guide, Chapters 1, 2, 3, and 5

Thank you

https://github.com/davegurnell/away-with-the-types

Dave Gurnell, @davegurnell

underscore