Relational Database Access

with *Slick*

Slick

Reactive Functional Relational Mapping for Scala

— *http://slick.lightbend.com*

- Library to access **relational databases**
- Can express **queries** in a **functional way** (`map`, `filter`…)
- Also supports **plain SQL**
- Supports asynchronicity (`Future`) and streaming (*Reactive Streams*)

Database **Profile**

Database Profile

- Many differences between databases and SQL dialects
- A **profile** allows
  - to unify peculiarities,
  - and also to benefit from proprietary features.

Tailoring a *PostgreSQL* Profile

```
// Extend PostgreSQL profile with java.time and Spray JSON support
trait ExtendedPostgresProfile extends ExPostgresProfile with PgDate2Support with PgSprayJsonSupport {
  val pgjson: String = "jsonb" // jsonb type for JSON column

  // Add 'insert or update' capability
  override protected def computeCapabilities: Set[Capability] =
    super.computeCapabilities + JdbcCapabilities.insertOrUpdate

  override val api: ExtendedAPI = ExtendedAPI
  // Add API support for Date and Time, and JSON
  trait ExtendedAPI extends API with DateTimeImplicits with JsonImplicits
  object ExtendedAPI extends ExtendedAPI
}

object ExtendedPostgresProfile extends ExtendedPostgresProfile
```

Importing API of the *PostgreSQL* Profile

```
import ExtendedPostgresProfile.api._
```

Import when in need to

- to connect to the **database**
- to describe **tables**,
- to describe **queries**,
- and more.

Describing **Tables** and Mapping **Records**

`Customers` Table and `Customer` Record

```
class Customers(tag: Tag) extends Table[Customer](tag, "customers") {
  def id = column[Long]("id", O.PrimaryKey, O.AutoInc)
  def firstName = column[String]("first_name")
  def lastName = column[String]("last_name")
  def * = (id.?, firstName, lastName).mapTo[Customer]

  def fullName = firstName ++ " " ++ lastName // Calculated column
}

object Customers {
  val table = TableQuery[Customers]
}

case class Customer(id: Option[Long], firstName: String, lastName: String)
```

Table Classes

Table Class describes a **table in a database**

- Name of **table** in database (`Table`)
- Name and type of **columns** in table (`column`)
- **Mapping** of table row to Record Class (`mapTo`, `<>`)
- Foreign keys (`foreignKey`)
- Indexes (`index`)
- Calculated columns

Record Classes

Record Class describes a **row in a table**

- Practically a **case class**
- **Strictly reflects table columns**, even foreign key columns
  - Might be a selection of columns
  - Might be **substructured**
  - Might use **custom column types**
- **Not part of the domain model**
  - Additional mapping to and from the model

When `mapTo` Does Not Compile

```
class Customers(tag: Tag) extends Table[Customer](tag, "customers") {
  def id = column[Long]("id", O.PrimaryKey, O.AutoInc)
  def firstName = column[String]("first_name")
  def lastName = column[String]("last_name")
  def * = (id.?, firstName, lastName) <> ((Customer.apply _).tupled, Customer.unapply)
}
```

Making Sense of <> Method

```
(id.?, firstName, lastName) <> ((Customer.apply _).tupled, Customer.unapply)
```

Part	Type
`Customer.apply _`	`(Option[Long], String, String) => Customer`
`(Customer.apply _).tupled`	`((Option[Long], String, String)) => Customer`
`Customer.unapply _`	`Customer => Option[(Option[Long], String, String)]`

`Orders` Table and `Order` Record

```
class Orders(tag: Tag) extends Table[Order](tag, "orders") {
  def id = column[Long]("id", O.PrimaryKey, O.AutoInc)
  def customerId = column[Long]("customer_id")
  def date = column[LocalDate]("date")
  def * = (id.?, customerId, date).mapTo[Order]

  def customer = foreignKey("fk_orders_customer_id", customerId, Customers.table)(_.id)
}

object Orders {
  val table = TableQuery[Orders]
}

case class Order(id: Option[Long], customerId: Long, date: LocalDate)
```

`OrderLines` Table and `OrderLine` Record

```
class OrderLines(tag: Tag) extends Table[OrderLine](tag, "order_lines") {
  def id = column[Long]("id", O.PrimaryKey, O.AutoInc)
  def orderId = column[Long]("order_id")
  def itemId = column[Long]("item_id")
  def quantity = column[Int]("quantity")
  def * = (id.?, orderId, itemId, quantity).mapTo[OrderLine]

  def order = foreignKey("fk_order_lines_order_id", orderId, Orders.table)(_.id)
  def item = foreignKey("fk_order_lines_item_id", itemId, Items.table)(_.id)
}

object OrderLines {
  val table = TableQuery[OrderLines]
}

case class OrderLine(id: Option[Long], orderId: Long, itemId: Long, quantity: Int)
```

`Items` Table and `Item` Record

```
class Items(tag: Tag) extends Table[Item](tag, "items") {
  def id = column[Long]("id", O.PrimaryKey, O.AutoInc)
  def name = column[String]("name")
  def * = (id.?, name).mapTo[Item]
}

object Items {
  val table = TableQuery[Items]
}

case class Item(id: Option[Long], name: String)
```

Substructuring a Record Class

Substructuring the record class

- `Customer` record class can have an `address` attribute of type `Address` that maps to some of the fields in the `customers` table.
- `Order` record can also hold a `billingAddress` and a `shippingAddress` (also of type `Address`), each mapping to different fields of the `orders` table.
- Much better than super flat record
- Also allows to overcome the 22 fields limit

Custom Column Types

Custom column types

- `Order` record class can have an attribute of enumeration type `OrderStatus`.
- `OrderStatus` can be declared as custom column type to be stored as `VARCHAR` in the `orders` table.

Describing **Queries** (`Query`)

Query (`Query`)

```
Query[+E, U, C[_]] /* extends Rep[C[U]] */
// E = SELECT Row Representation
// U = In-memory Row Class
// C = Collection Type (Seq, Set...)
```

- Describes a **`SELECT` query** retrieving **rows**
- Does **no side-effect**, just a query waiting to be run
- Must be **interpreted** against a **database** to do side-effects
- Will return a `C[U]` when run (for example `Seq[Customer]`)

Filtering (WHERE)

```
val selectCustomersQuery: Query[Customers, Customer, Seq] =
  Customers.table
    .filter(_.firstName.like("A%"))

val selectItemQuery: Query[Items, Item, Seq] =
  Items.table
    .filter(_.id === 1l)
```

Mapping (SELECT)

```
val selectFirstNameAndLastNameQuery:
  Query[(Rep[String], Rep[String]), (String, String), Seq] =
  Customers.table
    .filter(_.id =!= 1l)
    .map(c => (c.firstName, c.lastName))

val selectFullNameQuery:
  Query[Rep[String], String, Seq] =
  Customers.table
    .filter(_.firstName.startsWith("A"))
    .map(c => c.firstName ++ " " ++ c.lastName)
```

Joining (JOIN)

```
val selectOrdersAndOrderLinesQuery:
  Query[
    (Orders, Rep[Option[OrderLines]]),
    (Order, Option[OrderLine]),
    Seq
  ] =
  Orders.table joinLeft OrderLines.table on (_.id === _.orderId)
```

Sorting (ORDER BY)

```
val selectOrdersAndOrderLinesOrderedQuery =
  selectOrdersAndOrderLinesQuery
    .sortBy { case (order, maybeOrderLine) =>
      (order.id, maybeOrderLine.map(_.id))
    }
```

Advanced Queries

- Unioning (`UNION`, `UNION ALL`)
- Aggregating (`GROUP BY`)
- Plain SQL queries
  - `INTERSECT`, `EXCEPT`
  - Other advanced SQL features
- Compiled queries
  - Precompile a **parameterized query** for better performance

Describing **Database I/Os** (DBIO)

Database I/O (`DBIO`)

```
DBIO[A] // A = Result
```

- Describes a **program accessing a database**
- Does **no side-effect**, just a program waiting to be run
- Must be **interpreted** against a **database** to do side-effects
- When interpreted, it will either
  - **succeed** with a **result** of type `A`,
  - or **fail** holding an **exception**.

Querying (SELECT)

```
val selectCustomersDBIO: DBIO[Seq[Customer]] =
  selectCustomersQuery.result

val selectItemDBIO: DBIO[Option[Item]] =
  selectItemQuery.result.headOption

val selectOrdersAndOrderLinesOrderedDBIO: DBIO[Seq[(Order, Option[OrderLine])]] =
  selectOrdersAndOrderLinesOrderedQuery.result
```

Inserting (INSERT)

```
val insertCustomerDBIO: DBIO[Int] =
  Customers.table +=
    Customer(None, "April", "Jones")

val insertCustomersDBIO: DBIO[Seq[Customer]] =
  (Customers.table returning Customers.table) ++= Seq(
    Customer(None, "Anders", "Petersen"),
    Customer(None, "Pedro", "Sanchez"),
    Customer(None, "Natacha", "Borodine")
  )
```

Updating (UPDATE)

```
val updateCustomerDBIO: DBIO[Int] =
  Customers.table
    .filter(c => c.firstName === "Anders" && c.lastName === "Petersen")
    .map(c => (c.firstName, c.lastName))
    .update("Anton", "Peterson")
```

Deleting (DELETE)

```
val deleteCustomerDBIO: DBIO[Int] =
  Customers.table
    .filter(_.firstName === "April")
    .delete
```

Combining DBIOs into a DBIO Program

```
case class Result(insertedCustomers: Seq[Customer],
                  customers: Seq[Customer],
                  maybeItem: Option[Item],
                  ordersAndOrderLines: Seq[(Order, Option[OrderLine])])

val program: DBIO[Result] = for {
  _ <- insertCustomerDBIO
  insertedCustomers <- insertCustomersDBIO
  _ <- updateCustomerDBIO
  _ <- deleteCustomerDBIO
  customers <- selectCustomersDBIO
  maybeItem <- selectItemDBIO
  ordersAndOrderLines <- selectOrdersAndOrderLinesOrderedDBIO
} yield Result(insertedCustomers, customers, maybeItem, ordersAndOrderLines)
```

Making a `DBIO` Transactional

```
val transactionalProgram: DBIO[Result] = program.transactionally
```

- `transactionally` method results in a `DBIO` that will be run as a **single transaction**.
- Otherwise, each composing `DBIO` would be run in a separate transaction.

Running **Database I/Os** (DBIO)

Database Configuration (`application.conf`)

```
ecommerce {
  database {
    # http://slick.lightbend.com/doc/3.2.3/api/index.html#
    # slick.jdbc.JdbcBackend$DatabaseFactoryDef@forConfig(String,Config,Driver,ClassLoader):Database

    # numThreads = 200          # (Int, optional, default: 20)
    # queueSize = 100           # (Int, optional, default: 1000)

    # HikariCP Configuration (add "slick-hikaricp" dependency)
    url = "jdbc:postgresql://localhost:5432/ecommerce?currentSchema=ecommerce"
    driver = "org.postgresql.Driver"
    user = "ecommerceapi"
    password = "password"
    # isolation = SERIALIZABLE   # (String, optional)
    # maxConnections = 20        # (Int, optional, default: numThreads)
    # minConnections = 20        # (Int, optional, default: numThreads)
  }
}
```

Loading Database Configuration

```
// Load configuration from application.conf (using Lightbend Config library)
val config = ConfigFactory.load()

// Create database object from configuration
val database = Database.forConfig(
  "ecommerce.database",
  config
)
```

Running `DBIO` on Database

```
val eventualResult: Future[Result] = database.run(transactionalProgram)
```

- Interprets the program described by the `DBIO[A]` against a database
- Returns a `Future[A]`, a **promise** for a result that will eventually
  - **succeed** with a **result** of type `A`,
  - or **fail** holding an **exception**.
- Exception is just used as a value and is **never thrown**.

Handling `Future` Result

Handling **Success**

```
val eventualCompletion: Future[Unit] = for {
  Result(insertedCustomers, customers, maybeItem, ordersAndOrderLines) <- eventualResult
} yield {
  logger.info(s"insertedCustomers=$insertedCustomers")
  logger.info(s"customers=$customers")
  logger.info(s"maybeItem=$maybeItem")
  logger.info(s"ordersAndOrderLines=$ordersAndOrderLines")
}
```

Handling **Failure**

```
val eventualSafeCompletion: Future[Unit] = eventualCompletion
  .transform {
    case failure @ Failure(exception) =>
      // Log exception and keep failure as is
      logger.error("Exception occurred", exception)
      failure

    case success @ Success(_) =>
      // Keep success as is
      success
  }
  // Always close database after completion (either success or failure)
  .transformWith(_ => database.shutdown)
```

Waiting for **Completion**

```
Await.result(eventualSafeCompletion, 5.seconds)
```

- Will **block** until `Future` completes
  - Return the **result** in case of **success**
  - Raise the **exception** in case of a **failure**
  - **Timeout** after 5 seconds and fail with a `TimeoutException`
- Use this very sparingly!
- *Akka HTTP* handles futures directly without the hassle.

Combining **Database IOs** (DBIO)

Basic DBIOs

```
val success: DBIO[Int] = DBIO.successful(42)
// Will produce result 42 when run

val failure: DBIO[Nothing] = DBIO.failed(new IllegalStateException("Failure"))
// Will never produce a result and fail with IllegalStateException when run
```

Finding `Customer`, `Order` and `OrderLines`

```
def findCustomer(id: Long): DBIO[Customer] =
  Customers.table.filter(_.id === id).result.head

def findOrder(id: Long): DBIO[Order] =
  Orders.table.filter(_.id === id).result.head

def findOrderLines(orderId: Long): DBIO[Seq[OrderLine]] =
  OrderLines.table.filter(_.orderId === orderId).result
```

Transforming DBIO (map)

```
def findOrderDescription(orderId: Long): DBIO[String] = {
  findOrder(orderId).map { order =>
    s"Order #$orderId for customer #${order.customerId}"
  }
}
```

Transforming DBIO (for / yield)

```
def findOrderDescription(orderId: Long): DBIO[String] = {
  for {
    order <- findOrder(orderId)
  } yield s"Order #$orderId for customer #${order.customerId}"
}
```

Sequencing DBIOs (broken map)

```
def findOrderCustomer(orderId: Long): DBIO[DBIO[Customer]] = {
  findOrder(orderId).map { order =>
    findCustomer(order.customerId)
  }
}
```

- Wrong **nested** type `DBIO[DBIO[Customer]]`
- Needs to be made **flat** somehow as `DBIO[Customer]`

Sequencing DBIOs (flatMap)

```
def findOrderCustomer(orderId: Long): DBIO[Customer] = {
  findOrder(orderId).flatMap { order =>
    findCustomer(order.customerId)
  }
}
```

Sequencing DBIOs (for / yield)

```
def findOrderCustomer(orderId: Long): DBIO[Customer] = {
  for {
    order <- findOrder(orderId)
    customer <- findCustomer(order.customerId)
  } yield customer
}
```

Sequencing with Non-DBIO

```
for {
  order <- findOrder(orderId)
  customerId = order.customerId // Not a DBIO, '=' instead of '<-'
  orderLines <- findLines(orderId)
  customer <- findCustomer(customerId)
} yield Result(customer, order, orderLines)
```

Pyramid of `maps` and `flatMaps` 😈

```
def findOrderAndCustomerAndOrderLines(orderId: Long): DBIO[Result] =
  findOrder(orderId).flatMap { order =>
    findCustomer(order.customerId).flatMap { customer =>
      findLines(orderId).map { orderLines =>
        Result(customer, order, orderLines)
      }
    }
  }
```

Flatten Them All 😇

```
def findOrderAndCustomerAndOrderLines(orderId: Long): DBIO[Result] =
  for {
    order <- findOrder(orderId)
    customer <- findCustomer(order.customerId)
    orderLines <- findLines(orderId)
  } yield Result(customer, order, orderLines)
```

Anatomy of `for` Comprehension

`for` **comprehension is not a** `for` **loop**.

It can be a `for` loop...

But it can handle **many other things**

like `Option`, `Future` and... `DBIO`.

`for` Comprehension **Types**

```
def findOrderAndCustomerAndLines(orderId: Long): DBIO[Result] = {
  for {
    order      /* Order          */ <- findOrder(orderId)       /* DBIO[Order]          */
    customerId /* Long           */ =  order.id.get             /* Long                 */
    lines      /* Seq[OrderLine] */ <- findLines(order.id.get)  /* DBIO[Seq[OrderLine]] */
    customer   /* Customer       */ <- findCustomer(customerId) /* DBIO[Customer]       */
  } yield Result(customer, order, lines) /* Result */
} /* DBIO[Result] */
```

`for` Comprehension **Type Rules**

	`val` type	**operator**	**expression type**
generator	`A`	`<-`	`DBIO[A]`
assignment	`B`	`=`	`B`

	`for` comprehension type	**`yield` expression type**
result	`DBIO[R]`	`R`

- Combines **only `DBIO[T]`**, **no mix** with `Option[T]`, `Future[T]`, `Seq[T]`...
- But it could be **only** `Option[T]`, or **only** `Future[T]`, or **only** `Seq[T]`...

`for` Comprehension **Scopes**

```
def findOrderAndCustomerAndLines(orderId: Long): DBIO[Result] = {
  for {
    order <- findOrder(orderId)           /* order                    */
    customerId = order.id.get             /* 0    customerId          */
    lines <- findLines(order.id.get)      /* 0    |    orderLines     */
    customer<- findCustomer(customerId)   /* |    0    |    customer */
  } yield Result(customer, order, lines) /* 0    |    0    0         */
}
```

`for` Comprehension **Implicit Nesting**

```
def findOrderAndCustomerAndLines(orderId: Long): DBIO[Result] = {
  for {
       order <- findOrder(orderId)
    /* | */ customerId = order.id.get
    /* |    | */ lines <- findLines(order.id.get)
    /* |    |    | */ customer <- findCustomer(customerId)
  } /* |    |    |    | */ yield Result(customer, order, lines)
}
```

Visually flattens, but still implicitly nested

Conditions and Loops with **Database IOs** (DBIO)

A Tale of Free Welcome Order

- A free gift for every customer having never ordered anything
- Materialized by a fictitious order
- Let's call it *Free Welcome Order* or *FWO*
- Yes, this is a bit contrived 😉

Count Orders of a Customer

```
def findOrderCountByCustomerId(customerId: Long): DBIO[Int] =
  Orders.table
    .filter(_.customerId === customerId)
    .size // Rep[Int]
    .result
```

Insert FWO for a Customer

```
def insertFwoByCustomerId(customerId: Long): DBIO[Unit] =
  for {
    orderId <-
      (Orders.table returning Orders.table.map(_.id)) +=
        Order(None, customerId, LocalDate.now())

    _ <- OrderLines.table += OrderLine(None, orderId, 1, 1)
  } yield ()
```

Conditionally Insert FWO for a Customer

```
def conditionallyInsertFwo(customerId: Long): DBIO[Boolean] =
  for {
    orderCount <- findOrderCountByCustomerId(customerId)

    done <-
      if (orderCount == 0)
        insertFwoByCustomerId(customerId).flatMap(_ => DBIO.successful(true))
      else
        DBIO.successful(false)
  } yield done
```

Repeatedly Insert FWO for Customers

```
def repeatedlyInsertFwo(customerIds: Seq[Long]): DBIO[Seq[Boolean]] = {
  val seqOfDbio: Seq[DBIO[Boolean]] = customerIds.map(conditionallyInsertFwo)
  val dbioOfSeq: DBIO[Seq[Boolean]] = DBIO.sequence(seqOfDbio)
  dbioOfSeq
}
```

- Make a `Seq[DBIO[Boolean]]` using `map` over a `Seq[Long]`
- Turn it into a `DBIO[Seq[Boolean]]` using `DBIO.sequence`

Repeating with **Recursion** 😨

```
def insertCustomer(n: Int): DBIO[Int] =
  Customers.table += Customer(None, s"First Name $n", s"Last Name $n")

def insertCustomers(n: Int): DBIO[Int] =
  if (n > 0)
    for {
      count <- insertCustomer(n)
      restCount <- insertCustomers(n - 1) // Recursion
    } yield count + restCount
  else
    DBIO.successful(0)
```

Replacing Recursion with **Fold**

```
def insertCustomers(n: Int): DBIO[Int] = {
  val counts: Seq[DBIO[Int]] = (1 to n).map(insertCustomer)
  val totalCount: DBIO[Int] = DBIO.fold(counts, 0)(_ + _)
  totalCount
}
```

- Recursion can be hard to read
- Prefer using simpler alternatives whenever possible
  - `DBIO.sequence`
  - `DBIO.fold`

Further with *Slick*

Generating Table Creation Script

```
val schema =
  Customers.table.schema ++
    Orders.table.schema ++
    OrderLines.table.schema ++
    Items.table.schema

schema.createStatements.foreach(sql => println(s"$sql;"))
```

```
create table "customers" ("id" BIGSERIAL NOT NULL PRIMARY KEY,"first_name" VARCHAR NOT NULL,"last_name" VARCHAR NOT NULL);
create table "orders" ("id" BIGSERIAL NOT NULL PRIMARY KEY,"customer_id" BIGINT NOT NULL,"date" date NOT NULL);
create table "order_lines" ("id" BIGSERIAL NOT NULL PRIMARY KEY,"order_id" BIGINT NOT NULL,"item_id" BIGINT NOT NULL,"quantity" INTEGER NOT NULL);
create table "items" ("id" BIGSERIAL NOT NULL PRIMARY KEY,"name" VARCHAR NOT NULL);
alter table "orders" add constraint "fk_orders_customer_id" foreign key("customer_id") references "customers"("id") on update NO ACTION on delete NO ACTION;
alter table "order_lines" add constraint "fk_order_lines_item_id" foreign key("item_id") references "items"("id") on update NO ACTION on delete NO ACTION;
alter table "order_lines" add constraint "fk_order_lines_order_id" foreign key("order_id") references "orders"("id") on update NO ACTION on delete NO ACTION;
```

Testing for Existence

```
def findOrderExistenceByCustomerId(customerId: Long): DBIO[Boolean] =
  Orders.table
    .filter(_.customerId === customerId)
    .exists // Rep[Boolean]
    .result
```

- Avoid `.size` that counts all matching records
- Prefer `.exists` that stops on first matching record

`.headOption` vs `.head`

- `.result.headOption` **always succeeds** with an `Option[T]`
- `.result.head` **might succeed** with a `T` **or fail** with an exception
- Favor `.result.headOption`

Configuring *Slick* Logs in `logback.xml`

Be sure to add *Logback* dependency and a `logback.xml` file

```
<?xml version="1.0" encoding="UTF-8"?>
<configuration>
    <!-- ... -->
    <logger name="slick.basic" level="INFO"/>
    <logger name="slick.compiler" level="INFO"/>
    <logger name="slick.jdbc" level="DEBUG"/> <!-- Log SQL -->
    <logger name="slick.memory" level="INFO"/>
    <logger name="slick.relational" level="INFO"/>
    <logger name="slick.util" level="INFO"/>

    <logger name="com.zaxxer.hikari" level="INFO"/>
</configuration>
```

More about *Slick*

- Slick documentation
  - Queries
  - Database I/O Actions
  - Database Configuration
  - Logging with *SLF4J*
- Essential Slick book

Related Libraries Supported by *Slick*

- Lightbend Config, application configuration (`application.conf`)
- SL4J, logging facade
  - Already a dependency of *Slick*... and *Akka HTTP*
- Scala Logging, recommended Scala wrapper for *SLF4J*
- Logback, standard implementation for *SLF4J*
- HikariCP, database connection pool
- All compatible with *Akka HTTP*