ISIT312 Big Data Management

Spark Operations

Dr Fenghui Ren

School of Computing and Information Technology -
University of Wollongong

Spark Operations

Outline

The Programming Language Scala

Spark has built-in APIs for Java, Scala, and Python, and is also integrated with R

Among all languages, Scala is the most supported language

Also, Spark project is implemented using Scala

Therefore, we choose Scala as our working language in Spark

Scala is a Java-like programming language which unifies object-oriented and functional programming

Scala is a pure object-oriented language in the sense that every value is an object

Types and behaviour of objects are described by classes

Scala is a functional programming language in the sense that every function is a value

Nesting of function definitions and higher-order functions are naturally supported

The Programming Language Scala

`Hello World !` in Scala

Hello World ! in Scala

```
object Hello {
    def main(args: Array[String]) = {
        println("Hello, world")
    }
}
```

Instead of including `main` method, it can be extended with `App` trait

Extending App trait

```
object Hello2 extends App {
println("Hello, world")
}
```

Using command line arguments

Command line arguments

```
object HelloYou extends App {
    if (args.size == 0)
        println("Hello, you")
    else
        println("Hello, " + args(0))
}
```

The Programming Language Scala

Difference between `var`, `val`, and `def`

Variable

```
var x = 7
x = x * 2
```

Value

```
val x = 7
x = x * 2
'error: reassignment to val'
```

Function declaration

```
def hello(name: String) = "Hello : " + name
hello("James") // "Hello : James"
hello("")      // "Hello : "
```

When `lazy` keyword is used then a value is only computed when it is needed

Lazy evaluation

```
lazy val x = {
  println("calculating value of x")
  13 }
val y = {
  println("calculating value of y")
  20 }
```

The Programming Language Scala

Defining a class

Class Point

```
class Point(var x: Int, var y: Int) {
```

Method move

```
  def move(dx: Int, dy: Int): Unit = {
    x = x + dx
    y = y + dy
  }
```

Method toString

```
  override def toString: String =
    s"($x, $y)"
}
```

Applications

```
val point1 = new Point(2, 3)
println(point1.x)             // 2
println(point1)               // prints (2, 3)
```

Spark Operations

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Quick Start

To open Scala version of Spark shell in standalone mode process the following command

Starting Spark shell in standalone mode

```
bin/spark-shell --master local[*]
```

```
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /___/ .__/\_,_/_/ /_/\_\   version 1.0.0
      /_/

Using Scala version 2.10.4 (Java HotSpot(TM) 64-Bit Server VM, Java 1.7.0_60)
Type in expressions to have them evaluated.
Type :help for more information.
Spark context available as sc.

scala>
```

To open Spark shell shell with YARN, process the following command

Starting Spark shell with Yarn

```
bin/spark-shell --master yarn
```

Quick Start

A `SparkSession` instance is an entry to a Spark application

- If you type `spark` in the spark-shell interface then you get the following messages

Message

```
res0: org.apache.spark.sql.SparkSession = org.apache.spark.sql.SparkSession@...
```

You can use `SparkSession` instance `spark` to interact with Spark and to develop your data processing pipeline

For example,

Creating Data Frame

```
val myRange = spark.range(1000).toDF("number")
myRange: org.apache.spark.sql.DataFrame = [number: bigint]
```

Listing Data Frame

```
myRange.show(2)
+------+
|number|
+------+
|     0|
|     1|
+------+
only showing top 2 rows
```

Quick Start

Sample processing of a file `README.md`

Setting Spark Home folder

```
val YOUR_SPARK_HOME ="path-to-your-Spark-home"
```

Reading a text file

```
val textFile = spark.read.textFile("$YOUR_SPARK_HOME/README.md")
textFile: org.apache.spark.sql.Dataset[String] = [value: string]
```

Counting rows

```
textFile.count()
res0: Long = 104
```

Reading the first row

```
textFile.first()
res1: String = # Apache Spark
```

Filtering and counting rows

```
textFile.filter(line =>line.contains("Spark")).count()
res2: Long = 20
```

Quick Start

More operations on a file

Counting number of words in the longest line

```
textFile.map(line => line.split(" ").size).reduce((a, b) => if (a > b) a else b)
res3: Int = 22
```

Filtering and counting rows

```
val wordCounts = textFile.flatMap(line => line.split("")).groupByKey(identity).count()
wordCounts: org.apache.spark.sql.Dataset[(String, Long)] = [value: string, count(1): bigint]
```

Listing results

```
wordCounts.show(2)
+----------+--------+
|     value|count(1)|
+----------+--------+
|    online|       1|
|    graphs|       1|
+----------+--------+
only showing top 2 rows
```

Listing results

```
wordCounts.collect()
res7: Array[(String, Long)] = Array((online,1), (graphs,1), (["Parallel,1), (["Building,1), (thread,1),
(documentation,3), (command,,2), (abbreviated,1), (overview,1), (rich,1), (set,2), ...
```

Spark Operations

Outline

Self-Contained Application

A sample self-contained application

SimpleApp.scala

```
import org.apache.spark.sql.SparkSession
object SimpleApp {
  def main(args: Array[String]) {
    val logFile = "YOUR_SPARK_HOME/README.md"
   // Should be some file on your system
   val spark = SparkSession.builder
    .appName("Simple Application")
    .config("spark.master", "local[*]")
    .getOrCreate()
  val logData = spark.read.textFile(logFile).cache()
  val numAs = logData.filter(line => line.contains("a")).count()
  val numBs = logData.filter(line => line.contains("b")).count()
  println(s"Lines with a: $numAs, Lines with b: $numBs")
  spark.stop()
  }
}
```

Self-Contained Application

Compiling Scala source code using `scalac`

Compiling Scala source code

```
scalac -classpath "$SPARK_HOME/jars/*" SimpleApp.scala
```

Creating a jar file in the following way

Creating jar

```
jar cvf app.jar SimpleApp*.class
```

Process it with Spark-shell in the following way

Processing

```
$SPARK_HOME/bin/spark-submit --master local[*] --class SimpleApp app.jar
```

Spark Operations

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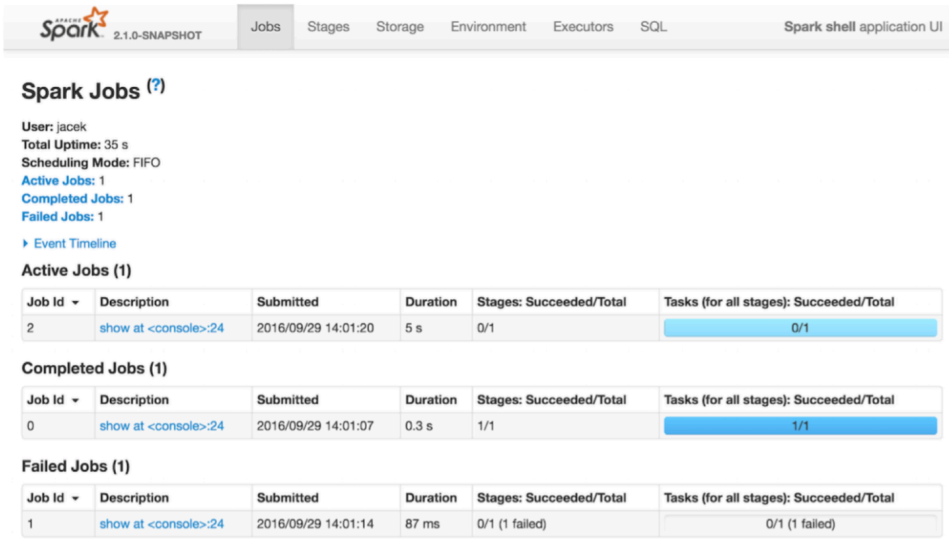
Web UI

Each driver program has a Web UI, typically on port 4040

Spark Web UI displays information about running tasks, executors, and storage usage.



Spark Operations

Outline

Operations on Resilient Distributed Datasets (RDDs)

Operations on RDDs are performed on raw Java or Scala objects

Creating a simple RDD with words and distributing over 2 partitions

Creating RDD

```
val myCollection = "Spark The Definitive Guide : Big Data Processing Made Simple".split(" ")
val words = spark.sparkContext.parallelize(myCollection, 2)
```

Eliminating duplicates and counting words

Distinct and counting

```
words.distinct().count()
```

Filtering

Filtering function

```
def startsWithS(individual:String) = { individual.startsWith("S") }
```

Filtering

```
val onlyS = words.filter(word => startsWithS(word))
```

Results of filtering

```
onlyS.collect()
```

Operations on Resilient Distributed Datasets (RDDs)

Sorting of RDD uses `sortBy` method and a function that extracts a value from the objects

Sorting

```
words.sortBy(word => word.length() * -1).take(2))
```

Random split into Array

Split into Array

```
val fiftyFiftySplit = words.randomSplit(Array[Double](0.5, 0.5))
```

Reduce RDD to one value

Reducing

```
def wordLengthReducer(leftWord:String, rightWord:String): String = {
  if (leftWord.length >= rightWord.length)
    return leftWord
  else
   return rightWord }
```

Reducing

```
words.reduce(wordLengthReducer)
```

Operations on Resilient Distributed Datasets (RDDs)

Some operations on RDDs are available on key-value pairs

The most common ones are distributed "shuffle" operations, such as grouping or aggregating the elements by a key

For example, `reduceByKey` operation on key-value pairs can be used to count how many times each line of text occurs in a file

Sorting

```
val lines = sc.textFile("data.txt")
val pairs = lines.map(s => (s, 1))
val counts = pairs.reduceByKey((a, b) => a + b)
```

Some of the transformations of RDDs

Transformations

```
map(func):                      passes each element of RDD through a function
filter(func):                   selects all element for which a function returns true
sample(withReplacement, fraction, seed): extracts  sample from RDD
union(otherDataset):            unions two RRDs
intersection(otherDataset):     finds intersection of two RDDs
distinct([numPartitions])):     eliminates duplicates
groupByKey([numPartitions]):    when called on RDD with (K, V) pairs, returns RDD with (K, Iterable) pairs
sortByKey([ascending], [numPartitions]: when called on (K, V) pairs where K implements Ordered,
                                returns (K, V) pairs sorted by keys
```

Spark Operations

Outline

Operations on Datasets

Operations on a Dataset start from creation of `case class`

Creating case class

```
case class Person(name: String, age: Long)
defined class Person
```

Creating Dataset

```
val caseClassDS = Seq(Person("Andy", 32)).toDS()
caseClassDS: org.apache.spark.sql.Dataset[Person] = [name: string, age: bigint]
```

Listing Dataset

```
caseClassDS.show()
+----+---+
|name|age|
+----+---+
|Andy| 32|
+----+---+
```

Dataset supports all operations of DataFrame

Using a Dataset

```
caseClassDS.select($"name").show()
+----+
|name|
+----+
|Andy|
+----+
```

Operations on Datasets

Operations on Datasets start from creation of `case class`

Creating case class

```
case class Flight(DEST_COUNTRY_NAME: String, ORIGIN_COUNTRY_NAME: String, count: BigInt)
```

Next we create a DataFrame

Creating DataFrame

```
val flightsDF = spark.read.parquet("/mnt/defg/chapter-1-data/parquet/2010-summary.parquet/")
```

Finally, DataFrame is casted to Dataset

Creating Dataset

```
val flights = flightsDF.as[Flight]
```

Filtering a Dataset

Defining a function

```
def originIsDestination(flight_row: Flight): Boolean = {
return flight_row.ORIGIN_COUNTRY_NAME == flight_row.DEST_COUNTRY_NAME}
```

Filtering

```
flights.filter(flight_row => originIsDestination(flight_row)).first()
```

Mapping a Dataset

Mapping

```
val destinations = flights.map(f => f.DEST_COUNTRY_NAME)
```

Spark Operations

Outline

Operations on DataFrames

Dataset and DataFrame are the data abstractions for Spark SQL

Dataset is a distributed collection of data

- It supports the use of self-defined functions to process data
- For example, `map` and `reduce` functions in the previous slides
- Dataset is typed; typing is checked at compiling time

DataFrame is a Dataset organized into named columns.

- It is conceptually equivalent to a table in a relational database or a data frame in R/Python
- To use self-defined functions, you need to register them with Spark
- DataFrame is untyped, i.e., typing is checked at runtime
- DataFrame is more performance-optimal than Dataset

Operations on DataFrames

DataFrame can be created in the following way

Creating a DataFrame

```
val df = spark.read.json("people.json")
df.show()
```

Results

```
+----+-------+
| age| name  |
+----+-------+
|null|Michael|
| 30 | Andy  |
| 19 | Justin|
+----+-------+
```

Results

```
df.printSchema()
```

Results

```
root
|-- age: long (nullable = true)
|-- name: string (nullable = true)
```

Operations on DataFrames

Select on a DataFrame

Selecting from a DataFrame

```
df.select($"name", $"age" + 1).show()
```

Results

```
+-------+---------+
| name  |(age + 1)|
+-------+---------+
|Michael|     null|
|   Andy|       31|
| Justin|       20|
+-------+---------+
```

Filtering a DataFrame

```
df.filter($"age" > 21).show()
```

Results

```
+---+----+
|age|name|
+---+----+
| 30|Andy|
+---+----+
```

Operations on DataFrames

Count people by age

Counting in a DataFrame

```
df.groupBy("age".count().show()
```

Results

```
+----+-----+
| age|count|
+----+-----+
|  19|    1|
|null|    1|
|  30|    1|
+----+-----+
```

Operations on DataFrames

Register a DataFrame as SQL temporary view

Registering and selecting from DataFrame

```
df.createOrReplaceTempView("people")
val sqlDF = spark.sql("SELECT * FROM people")
sqlDF.show()
```

Results

```
+----+-------+
| age| name  |
+----+-------+
|null|Michael|
|30  | Andy  |
|19  | Justin|
+----+-------+
```

Operations on DataFrames

When to use DataFrames ?

Except for the following few cases, you can use them interchangeable (if performance is not a concern). You also can convert one to the other easily.

- In the Bigdata pipeline, you read an unstructured data source, for example, a text file as a Dataset and continue processing the data
- You can directly read an structured source like Hive table, JSON document as a DataFrame
- If you expect to use self-defined function easily, especially in the data cleaning or preprocessing stage of the pipeline, you should use a Dataset

Operations on DataFrames

Create a Dataset of `Person` objects from a text file and convert it to a DataFrame

Converting a Dataset to DataFrame

```
val peopleDF = spark.sparkContext
.textFile("examples/src/main/resources/people.txt")
.map(_.split(","))
.map(attributes => Person(attributes(0), attributes(1).trim.toInt))
.toDF()
```

Results

```
peopleDF: org.apache.spark.sql.DataFrame = [name: string, age: bigint]
```

Operations on DataFrames

Convert DataFrame to Dataset

Converting a Dataset to DataFrame

```
case class  Employee(name: String, salary: Long)
val ds =
     spark.read.json(".../examples/src/main/resources/employees.json").as[Employee]
```

Results

```
ds: org.apache.spark.sql.Dataset[Employee] = [name: string, salary: bigint]
```

Operations on DataFrames

Spark DataFrame/Dataset support two types of operations: transformations and actions

Transformations are operations on DataFrames/Datasets that return a new DataFrame/Dataset

- For example `select()`, `groupBy()`, `map()`, and `filter()`

Actions are operations that return a result to the driver program or write it to storage, and kick off a computation

- For example `show()`, `count()`, and `first()`

Return type difference: transformations return DataFrames/Datasets, whereas actions return some other data type

Spark treats the two operations very differently

Operations on DataFrames

Transformations are lazily evaluated, meaning that Spark will not begin to execute until it sees an action

Instead, Spark internally records metadata to indicate that some transformation operation has been requested

For example transformation creates another DataFrame

Creating a DataFrame

```
val sqlDF = spark.sql("SELECT * FROM people")
```

Action triggers the computation

Action on a DataFrame

```
sqlDF.show()
```

Operations on DataFrames

The lazy evaluation to reduce the number of passes it has to take over the dataset

In Hadoop MapReduce, developers often have to consider how to group together operations to minimize the number of MapReduce passes

In Spark, there is no substantial benefit to writing a single complex map instead of chaining together many simple operations

Thus, users are free to organize their program into smaller, more manageable operations

Spark Operations

Outline

Spark SQL

Spark SQL is a Spark module for general data processing and analytics

It can be used for all sorts of data, from unstructured log files to semi-structured CSV files and highly structured Parquet files

To interact with Spark SQL, you can either use SQL or Spark Structured API, or both

The same execution engine is used, independent of which API/language you use to express the computation

The APIs of Spark SQL provide a rich set of pre-built, high-level operations for accomplishing sophisticate data processing and ETL jobs, and mechanism to implement your own operations, for example self-defined functions and aggregations

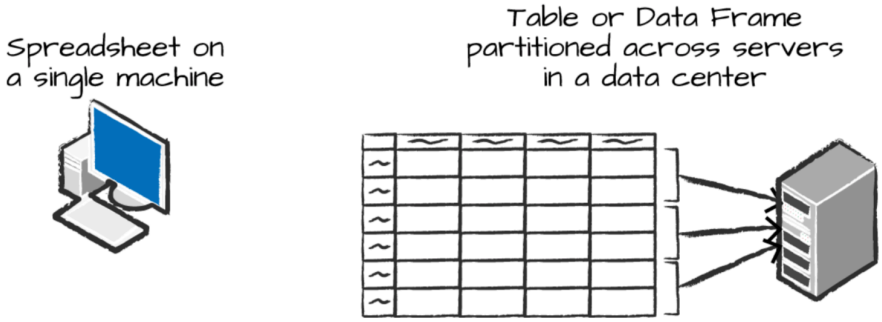
Spark SQL

Spark SQL has two data abstractions

- DataFrame
- Dataset (available in Scala/Java APIs, but not Python/R APIs)
- DataFrame can be represented as SQL tables and views

Both are distributed table-like collections with well-defined rows and columns.

- DataFrame vs. spreadsheet



Spark SQL

Spark SQL allows to code SQL statements in Scala, Java and Python language APIs.

To use SQL to manipulate a DataFrame, we first need to create a temporal view for it

Creating a temporal view

```
df.createOrReplaceTempView("dfTable")
```

All standard SQL statements + functions are applicable in Spark SQL

Spark implements a subset of ANSI SQL:2003

Spark SQL

Using SQL

Applying sql method

```
spark.sql(
"SELECT DEST_COUNTRY_NAME, sum(count)
 FROM dfTable
 GROUP BY DEST_COUNTRY_NAME"
)
.where("DEST_COUNTRY_NAME like 'S%'")
.where("'sum(count)' > 10")
.show(2)
```

Results

```
+-----------------+----------+
|DEST_COUNTRY_NAME|sum(count)|
+-----------------+----------+
| Senegal         | 40       |
| Sweden          | 118      |
+-----------------+----------+
```

References

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