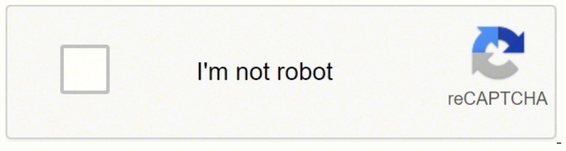

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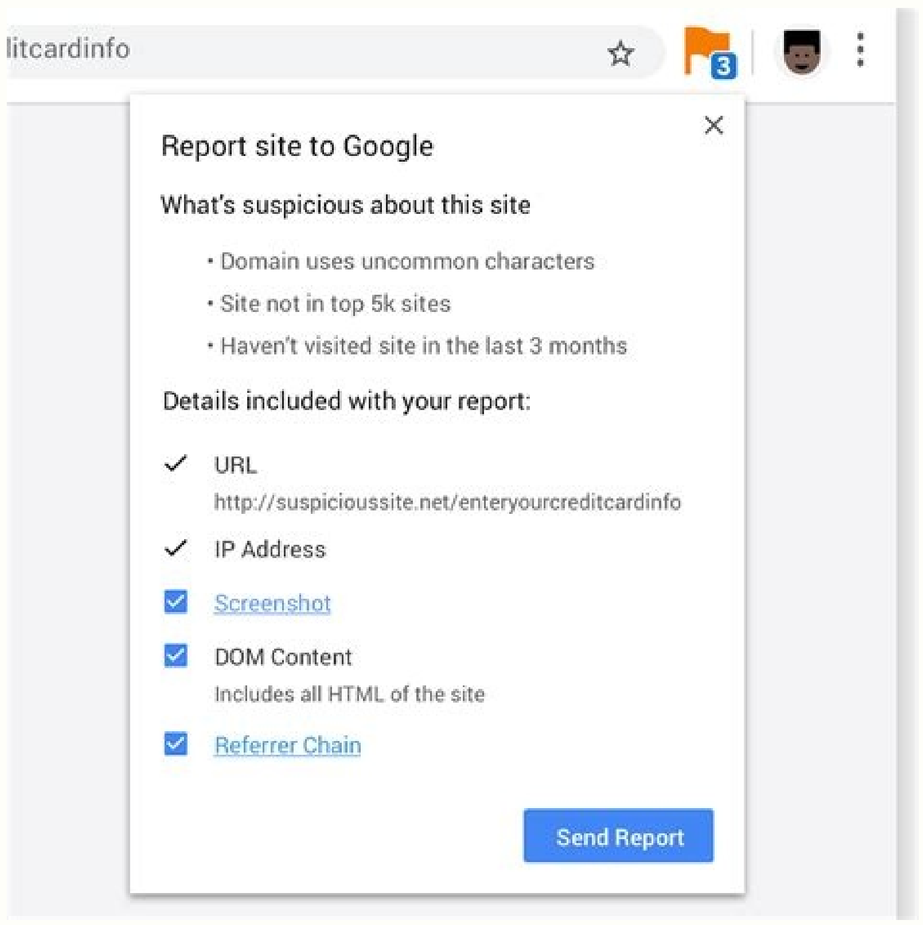
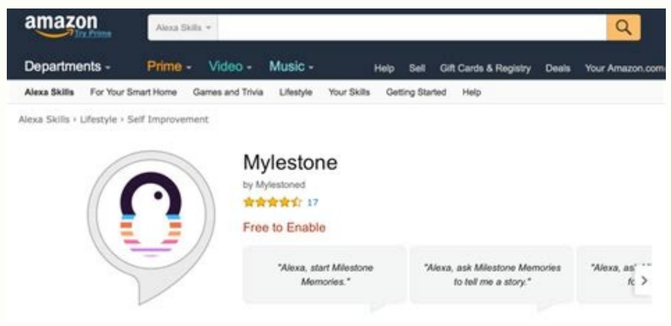
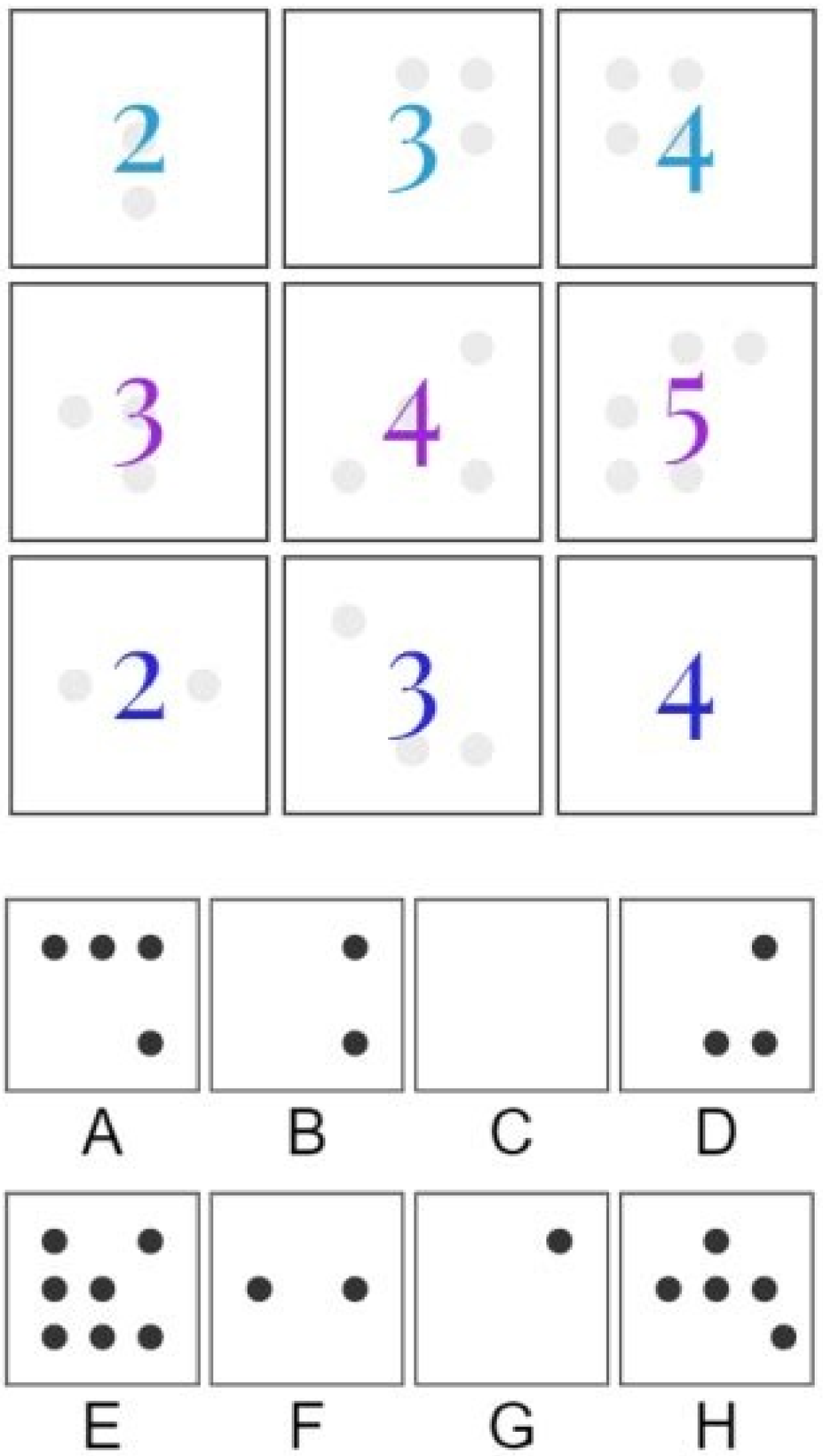




THE PAYOFF. This huge trophy, the Pepsi Cola award, is presented to Standard-Triumph's president Chris Andrews at the New York Automobile Show — in front of transplanted car number 42. Making the presentation is Edward C. Finneran, manager of the sports division of The Pepsi Cola Co. The trophy is inscribed with names of all the winning drivers.



Let’s make a new DataFrame from the text of the README file in the Spark source directory: >>> textFile = spark.read.text("README.md") You can get values from DataFrame directly, by calling some actions, or transform the DataFrame to get a new one. [info] Packaging {..}/{..}/target/scala-2.12/simple-project_2.12-1.0.jar # Use spark-submit to run your application $ YOUR_SPARK_HOME/bin/spark-submit \ --class "SimpleApp" \ --master local[4] \ target/scala-2.12/simple-project_2.12-1.0.jar ... This tutorial provides a quick introduction to using Spark. ./pom.xml ./src ./src/main ./src/main/java ./src/main/java/SimpleApp.java Now, we can package the application using Maven and execute it with ./bin/spark-submit. We will walk through a simple application in Scala (with sbt), Java (with Maven), and Python (pip). Note that Spark artifacts are tagged with a Scala version. Once that is in place, we can create a JAR package containing the application’s code, then use the spark-submit script to run our program. Let’s say we want to find the line with the most words: scala> textFile.map(line => line.split(" ").size).reduce((a, b) => if (a > b) a else b) res4: Long = 15 This first maps a line to an integer value, creating a new Dataset. edu.berkeley simple-project 4.0.0 Simple Project jar 1.0 org.apache.spark spark-sql_2.12 3.2.1 provided We lay out these files according to the canonical Maven directory structure: $ find . After Spark 2.0, RDDs are replaced by Dataset, which is strongly-typed like an RDD, but with richer optimizations under the hood. >>> linesWithSpark.cache() >>> linesWithSpark.count() 15 >>> linesWithSpark.count() 15 It may seem silly to use Spark to explore and cache a 100-line text file. As a result, all Datasets in Python are Dataset[Row], and we call it DataFrame to be consistent with the data frame concept in Pandas and R. See the SQL programming guide to get more information about Dataset. Self-Contained Applications Suppose we wish to write a self-contained application using the Spark API. To follow along with this guide, first, download a packaged release of Spark from the Spark website. . Subclasses of scala.App may not work correctly. We call SparkSession.builder to construct a SparkSession, then set the application name, and finally call getOrCreate to get the SparkSession instance. Due to Python’s dynamic nature, we don’t need the Dataset to be strongly-typed in Python. Spark can implement MapReduce flows easily: >>> wordCounts = textFile.select(explode(split(textFile.value, "\s+")).alias("word")).groupBy("word").count() Here, we use the explode function in select, to transform a Dataset of lines to a Dataset of words, and then combine groupBy and count to compute the per-word counts in the file as a DataFrame of 2 columns: “word” and “count”. >>> linesWithSpark = textFile.filter(textFile.value.contains("Spark")) We can chain together transformations and actions: >>> textFile.filter(textFile.value.contains("Spark")).count() # How many lines contain "Spark"? Note that you’ll need to replace YOUR_SPARK_HOME with the location where Spark is installed. Note that you’ll need to replace YOUR_SPARK_HOME with the location where Spark is installed. Where to Go from Here Congratulations on running your first Spark application! # For Scala and Java, use run-example: ./bin/run-example SparkPi # For Python examples, use spark-submit directly: ./bin/spark-submit examples/src/main/python/pi.py # For R examples, use spark-submit directly: ./bin/spark-submit examples/src/main/r/dataframe.R The arguments to map and reduce are Scala function literals (closures), and can use any language feature or Scala/Java library. For example, we can easily call functions declared elsewhere. You can also do this interactively by connecting bin/spark-shell to a cluster, as described in the RDD programming guide. This file also adds a repository that Spark depends on: name := "Simple Project" version := "1.0" scalaVersion := "2.12.15" libraryDependencies += "org.apache.spark" %% "spark-sql" % "3.2.1" For sbt to work correctly, we’ll need to layout SimpleApp.scala and build.sbt according to the typical directory structure. Since we won’t be using HDFS, you can download a package for any version of Hadoop. To build the program, we also write a Maven pom.xml file that lists Spark as a dependency. For more details, please read the API doc. res3: Long = 15 Or if PySpark is installed with pip in your current environment: Spark’s primary abstraction is a distributed collection of items called a Dataset. ./build.sbt ./src ./src/main ./src/main/scala ./src/main/scala/SimpleApp.scala # Package a jar containing your application $ sbt package ... We’ll use Math.max() function to make this code easier to understand: scala> import java.lang.Math import java.lang.Math scala> textFile.map(line => line.split(" ").size).reduce((a, b) => Math.max(a, b)) res5: Int = 15 One common data flow pattern is MapReduce, as popularized by Hadoop. The arguments to select and agg are both Column, we can use df.colName to get a column from a DataFrame. However, we highly recommend you to switch to use Dataset, which has better performance than RDD. SimpleApp is simple enough that we do not need to specify any code dependencies. One common data flow pattern is MapReduce, as popularized by Hadoop. Datasets can be created from Hadoop InputFormats (such as HDFS files) or by transforming other Datasets. # Your directory layout should look like this $ find . For applications that use custom classes or third-party libraries, we can also add code dependencies to spark-submit through its --py-files argument by packaging them into a .zip file (see spark-submit --help for details). scala> textFile.count() // Number of items in this Dataset res0: Long = 126 // May be different from yours as README.md will change over time, similar to other outputs scala> textFile.first() // First item in this Dataset res1: String = # Apache Spark Now let’s transform this Dataset into a new one. You can also do this interactively by connecting bin/pyspark to a cluster, as described in the RDD programming guide. If you are building a packaged PySpark application or library you can add it to your setup.py file as: install_requires=['pyspark==3.2.1'] As an example, we’ll create a simple Spark application, SimpleApp.py: """SimpleApp.py""" from pyspark.sql import SparkSession logFile = "YOUR_SPARK_HOME/README.md" # Should be some file on your system spark = SparkSession.builder.appName("SimpleApp").getOrCreate() logData = spark.read.text(logFile).cache() numAs = logData.filter(logData.value.contains('a')).count() numBs = logData.filter(logData.value.contains('b')).count() print("Lines with a: %i, lines with b: %i" % (numAs, numBs)) spark.stop() This program just counts the number of lines containing ‘a’ and the number containing ‘b’ in a text file. Lines with a: 46, Lines with b: 23 Other dependency management tools such as Conda and pip can be also used for custom classes or third-party libraries. The interesting part is that these same functions can be used on very large data sets, even when they are striped across tens or hundreds of nodes. [INFO] Building jar: {..}/{..}/target/simple-project-1.0.jar # Use spark-submit to run your application $ YOUR_SPARK_HOME/bin/spark-submit \ --class "SimpleApp" \ --master local[4] \ target/simple-project-1.0.jar ... Unlike the earlier examples with the Spark shell, which initializes its own SparkSession, we initialize a SparkSession as part of the program. >>> textFile.count() # Number of rows in this DataFrame 126 >>> textFile.first() # First row in this DataFrame Row(value=u'# Apache Spark') Now let’s transform this DataFrame to a new one. To collect the word counts in our shell, we can call collect: scala> wordCounts.collect() res6: Array[(String, Int)] = Array((means,1), (under,2), (this,3), (Because,1), (Python,2), (agree,1), (cluster.,1), ...) >>> from pyspark.sql.functions import * >>> textFile.select(size(split(textFile.value, "\s+")).name("numWords")).agg(max(col("numWords"))).collect() [Row(max(numWords)=15)] This first maps a line to an integer value and aliases it as “numWords”, creating a new DataFrame. This is very useful when data is accessed repeatedly, such as when querying a small “hot” dataset or when running an iterative algorithm like PageRank. # Package a JAR containing your application $ mvn package ... We can run this application using the bin/spark-submit script: # Use spark-submit to run your application $ YOUR_SPARK_HOME/bin/spark-submit \ --master local[4] \ SimpleApp.py ... The RDD interface is still supported, and you can get a more detailed reference at the RDD programming guide. Interactive Analysis with the Spark Shell Spark’s shell provides a simple way to learn the API, as well as a powerful tool to analyze data interactively. We call filter to return a new Dataset with a subset of the items in the file. Start it by running the following in the Spark directory: Spark’s primary abstraction is a distributed collection of items called a Dataset. # Use the Python interpreter to run your application $ python SimpleApp.py ... Spark can implement MapReduce flows easily: scala> val wordCounts = textFile.flatMap(line => line.split(" ")).groupByKey(identity).count() wordCounts: org.apache.spark.sql.Dataset[(String, Long)] = [value: string, count(1): bigint] Here, we call flatMap to transform a Dataset of lines to a Dataset of words, and then combine groupByKey and count to compute the per-word counts in the file as a Dataset of (String, Long) pairs. scala> val linesWithSpark = textFile.filter(line => line.contains("Spark")) linesWithSpark: org.apache.spark.sql.Dataset[String] = [value: string] We can chain together transformations and actions: scala> textFile.filter(line => line.contains("Spark")).count() // How many lines contain "Spark"? We’ll create a very simple Spark application in Scala–so simple, in fact, that it’s named SimpleApp.scala: /* 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").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() } } Note that applications should define a main() method instead of extending scala.App. We call filter to return a new DataFrame with a subset of the lines in the file. We can also import pyspark.sql.functions, which provides a lot of convenient functions to build a new Column from an old one. agg is called on that DataFrame to find the largest word count. To collect the word counts in our shell, we can call collect: >>> wordCounts.collect() [Row(word=u'online', count=1), Row(word=u'graphs', count=1), ...] Caching Spark also supports pulling data sets into a cluster-wide in-memory cache. Lines with a: 46, Lines with b: 23 Now we will show how to write an application using the Python API (PySpark). 15 More on Dataset Operations Dataset actions and transformations can be used for more complex computations. We’ll create a very simple Spark application, SimpleApp.java: /* SimpleApp.java */ import org.apache.spark.sql.SparkSession; import org.apache.spark.sql.Dataset; public class SimpleApp { public static void main(String[] args) { String logFile = "YOUR_SPARK_HOME/README.md"; // Should be some file on your system SparkSession spark = SparkSession.builder().appName("Simple Application").getOrCreate(); Dataset logData = spark.read().textFile(logFile).cache(); long numAs = logData.filter(s -> s.contains("a")).count(); long numBs = logData.filter(s -> s.contains("b")).count(); System.out.println("Lines with a: " + numAs + ", lines with b: " + numBs); spark.stop(); } } This program just counts the number of lines containing ‘a’ and the number containing ‘b’ in the Spark README. This program just counts the number of lines containing ‘a’ and the number containing ‘b’ in the Spark README. Let’s make a new Dataset from the text of the README file in the Spark source directory: scala> val textFile = spark.read.textFile("README.md") textFile: org.apache.spark.sql.Dataset[String] = [value: string] You can get values from Dataset directly, by calling some actions, or transform the Dataset to get a new one. Our application depends on the Spark API, so we’ll also include an sbt configuration file, build.sbt, which explains that Spark is a dependency. It is available in either Scala (which runs on the Java VM and is thus a good way to use existing Java libraries) or Python. As a simple example, let’s mark our linesWithSpark dataset to be cached: scala> linesWithSpark.cache() res7: linesWithSpark.type = [value: string] scala> linesWithSpark.count() res8: Long = 15 scala> linesWithSpark.count() res9: Long = 15 It may seem silly to use Spark to explore and cache a 100-line text file. See also Python Package Management. Lines with a: 46, Lines with b: 23 This example will use Maven to compile an application JAR, but any similar build system will work. As with the Scala and Java examples, we use a SparkSession to create Datasets. Note that, before Spark 2.0, the main programming interface of Spark was the Resilient Distributed Dataset (RDD). reduce is called on that Dataset to find the largest word count. We will first introduce the API through Spark’s interactive shell (in Python or Scala), then show how to write applications in Java, Scala, and Python. Lines with a: 46, Lines with b: 23 If you have PySpark pip installed into your environment (e.g., pip install pyspark), you can run your application with the regular Python interpreter or use the provided ‘spark-submit’ as you prefer.

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