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Spark Tutorial: Learning Apache Spark

This tutorial will teach you how to use Apache Spark (http://spark.apache.org/), a framework for large-scale data processing, within a notebook. Many traditional frameworks were designed to be run on a single computer. However, many datasets today are too large to be stored on a single computer, and even when a dataset can be stored on one computer (such as the datasets in this tutorial), the dataset can often be processed much more quickly using multiple computers.

Spark has efficient implementations of a number of transformations and actions that can be composed together to perform data processing and analysis. Spark excels at distributing these operations across a cluster while abstracting away many of the underlying implementation details. Spark has been designed with a focus on scalability and efficiency. With Spark you can begin developing your solution on your laptop, using a small dataset, and then use that same code to process terabytes or even petabytes across a distributed cluster.

During this tutorial we will cover:

- *Part 1:* Basic notebook usage and Python (https://docs.python.org/2/) integration
- *Part 2:* An introduction to using Apache Spark (https://spark.apache.org/) with the PySpark SQL API (http://spark.apache.org/docs/latest/api/python/pyspark.sql.html#pyspark-sql-module) running in a notebook
- *Part 3:* Using DataFrames and chaining together transformations and actions
- *Part 4*: Python Lambda functions and User Defined Functions
- *Part 5:* Additional DataFrame actions
- *Part 6:* Additional DataFrame transformations
- *Part 7:* Caching DataFrames and storage options
- *Part 8:* Debugging Spark applications and lazy evaluation

The following transformations will be covered:

- `select()`, `filter()`, `distinct()`, `dropDuplicates()`, `orderBy()`, `groupBy()`

The following actions will be covered:

- `first()`, `take()`, `count()`, `collect()`, `show()`

Also covered:

- `cache()`, `unpersist()`

Note that, for reference, you can look up the details of these methods in the Spark's PySpark SQL API (http://spark.apache.org/docs/latest/api/python/pyspark.sql.html#pyspark-sql-module)

Part 1: Basic notebook usage and Python (https://docs.python.org/2/) integration

(1a) Notebook usage

A notebook is comprised of a linear sequence of cells. These cells can contain either markdown or code, but we won't mix both in one cell. When a markdown cell is executed it renders formatted text, images, and links just like HTML in a normal webpage. The text you are reading right now is part of a markdown cell. Python code cells allow you to execute arbitrary Python commands just like in any Python shell. Place your cursor inside the cell below, and press "Shift" + "Enter" to execute the code and advance to the next cell. You can also press "Ctrl" + "Enter" to execute the code and remain in the cell. These commands work the same in both markdown and code cells.

In [2]:
```
# This is a Python cell. You can run normal Python code here...
print 'The sum of 1 and 1 is {0}'.format(1+1)
```

```
The sum of 1 and 1 is 2
```

In [3]:
```
# Here is another Python cell, this time with a variable (x) declaration
 and an if statement:
x = 42
if x > 40:
    print 'The sum of 1 and 2 is {0}'.format(1+2)
```

```
The sum of 1 and 2 is 3
```

(1b) Notebook state

As you work through a notebook it is important that you run all of the code cells. The notebook is stateful, which means that variables and their values are retained until the notebook is detached or the kernel is restarted (in Jupyter notebooks). If you do not run all of the code cells as you proceed through the notebook, your variables will not be properly initialized and later code might fail. You will also need to rerun any cells that you have modified in order for the changes to be available to other cells.

In [4]:
```
# This cell relies on x being defined already.
# If we didn't run the cells from part (1a) this code would fail.
print x * 2
```

```
84
```

(1c) Library imports

We can import standard Python libraries (modules (https://docs.python.org/2/tutorial/modules.html)) the usual way. An `import` statement will import the specified module. In this tutorial and future labs, we will provide any imports that are necessary.

In [5]:
```
# Import the regular expression library
import re
m = re.search('(?<=abc)def', 'abcdef')
m.group(0)
```

Out[5]:
```
def
```

In [6]:
```
# Import the datetime library
import datetime
print 'This was last run on: {0}'.format(datetime.datetime.now())
```

```
This was last run on: 2016-12-08 12:37:05.959206
```

Part 2: An introduction to using Apache Spark (https://spark.apache.org/) with the PySpark SQL API (http://spark.apache.org/docs/latest/api/python/pyspark.sql.html#py sql-module) running in a notebook

Spark Context

In Spark, communication occurs between a driver and executors. The driver has Spark jobs that it needs to run and these jobs are split into tasks that are submitted to the executors for completion. The results from these tasks are delivered back to the driver.

In part 1, we saw that normal Python code can be executed via cells. When using spark-submit this code gets executed in the Spark driver's Java Virtual Machine (JVM) and not in an executor's JVM, and when using a Jupyter notebook it is executed within the kernel associated with the notebook. Since no Spark functionality is actually being used, no tasks are launched on the executors.

In order to use Spark and its DataFrame API we will need to use a `SQLContext`. When running Spark, you start a new Spark application by creating a SparkContext (http://spark.apache.org/docs/latest/api/python/pyspark.html#pyspark.SparkContext). You can then create a SQLContext (http://spark.apache.org/docs/latest/api/python/pyspark.sql.html#pyspark.sql.SQLContext) from the `SparkContext`. When the `SparkContext` is created, it asks the master for some cores to use to do work. The master sets these cores aside just for you; they won't be used for other applications. When using Jupyter, both a `SparkContext` is created for you automatically. `sc` is your `SparkContext`.

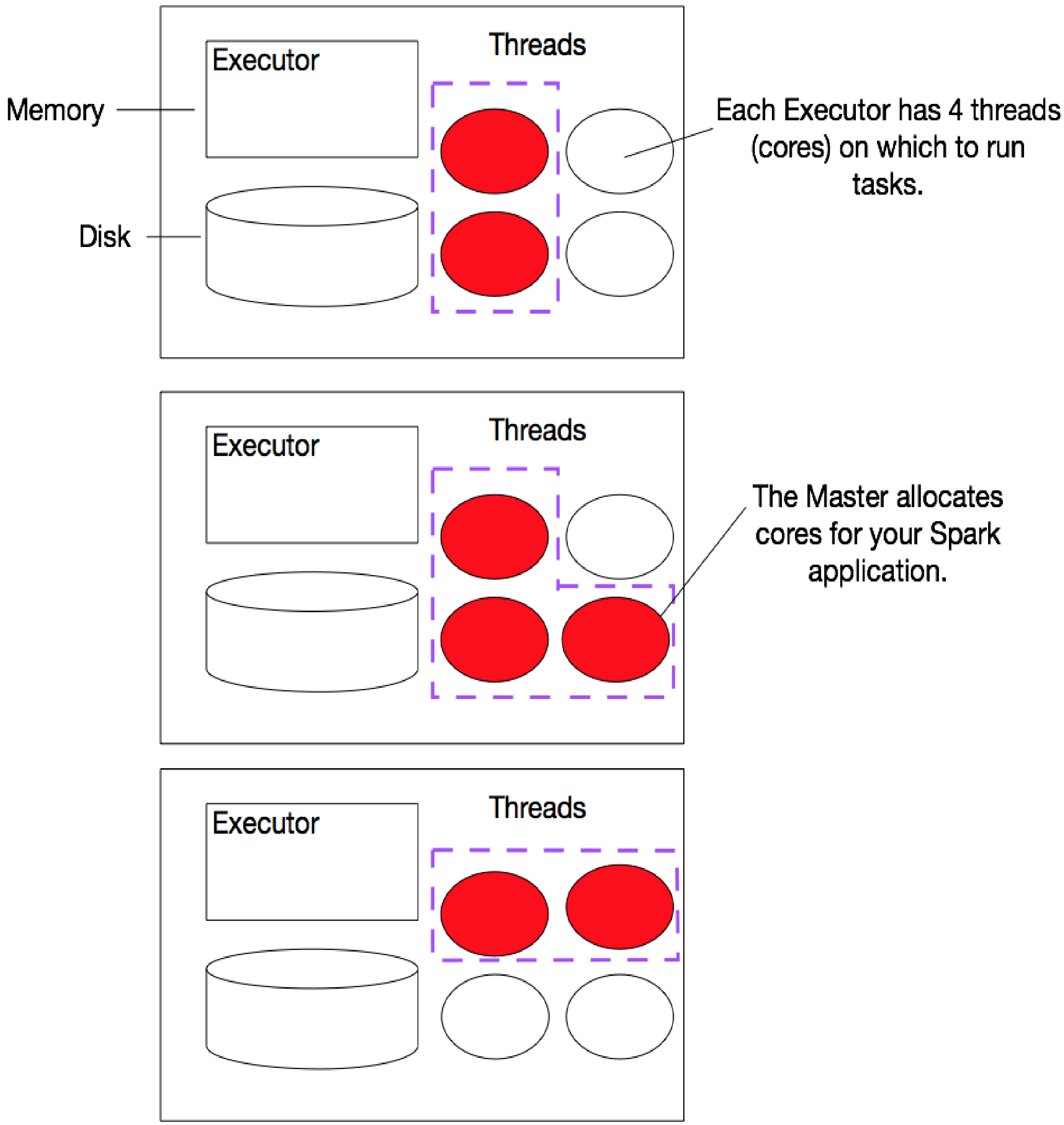
(2a) Example Cluster

The diagram shows an example cluster, where the slots allocated for an application are outlined in purple. (Note: We're using the term *slots* here to indicate threads available to perform parallel work for Spark. Spark documentation often refers to these threads as *cores*, which is a confusing term, as the number of slots available on a particular machine does not necessarily have any relationship to the number of physical CPU cores on that machine.)

You can view the details of your Spark application in the Spark web UI. In the web UI, under the "Jobs" tab, you can see a list of jobs that have been scheduled or run. It's likely there isn't any thing interesting here yet because we haven't run any jobs, but we'll return to this page later.

At a high level, every Spark application consists of a driver program that launches various parallel operations on executor Java Virtual Machines (JVMs) running either in a cluster or locally on the same machine. In Jupyter, "Spark Shell" is the driver program. When running locally, `pyspark` is the driver program. In all cases, this driver program contains the main loop for the program and creates distributed datasets on the cluster, then applies operations (transformations & actions) to those datasets. Driver programs access Spark through a SparkContext object, which represents a connection to a computing cluster. A Spark SQL context object (`sqlContext`) is the main entry point for Spark DataFrame and SQL functionality. A `SQLContext` can be used to create DataFrames, which allows you to direct the operations on your data.

Try printing out `sqlContext` to see its type.



In [7]:
```
# Display the type of the Spark sqlContext
type(sqlContext)
```

Out[7]: <class 'pyspark.sql.context.SQLContext'>

Note that the type is `HiveContext`. This means we're working with a version of Spark that has Hive support. Compiling Spark with Hive support is a good idea, even if you don't have a Hive metastore. As the Spark Programming Guide (http://spark.apache.org/docs/latest/sql-programming-guide.html#starting-point-sqlcontext) states, a `HiveContext` "provides a superset of the functionality provided by the basic `SQLContext`. Additional features include the ability to write queries using the more complete HiveQL parser, access to Hive UDFs [user-defined functions], and the ability to read data from Hive tables. To use a `HiveContext`, you do not need to have an existing Hive setup, and all of the data sources available to a `SQLContext` are still available."

(2b) SparkContext attributes

You can use Python's dir() (https://docs.python.org/2/library/functions.html?highlight=dir#dir) function to get a list of all the attributes (including methods) accessible through the `sqlContext` object.

In [8]:

```
# List sqlContext's attributes
dir(sqlContext)
```

Out[8]:

```
['__class__', '__delattr__', '__dict__', '__doc__', '__format__', '__ge
tattribute__', '__hash__', '__init__', '__module__', '__new__', '__redu
ce__', '__reduce_ex__', '__repr__', '__setattr__', '__sizeof__', '__str
__', '__subclasshook__', '__weakref__', '_createFromLocal', '_createFro
mRDD', '_inferSchema', '_inferSchemaFromList', '_jsc', '_jvm', '_sc',
 '_scala_SQLContext', '_ssql_ctx', 'applySchema', 'cacheTable', 'clearC
ache', 'createDataFrame', 'createExternalTable', 'getConf', 'inferSchem
a', 'jsonFile', 'jsonRDD', 'load', 'parquetFile', 'range', 'read', 'reg
isterDataFrameAsTable', 'registerFunction', 'setConf', 'sql', 'table',
 'tableNames', 'tables', 'udf', 'uncacheTable']
```

(2c) Getting help

Alternatively, you can use Python's help() (https://docs.python.org/2/library/functions.html?highlight=help#help) function to get an easier to read list of all the attributes, including examples, that the `sqlContext` object has.

In [9]:

```
# Use help to obtain more detailed information
help(sqlContext)
```

```
Help on SQLContext in module pyspark.sql.context object:

class SQLContext(__builtin__.object)
 |  Main entry point for Spark SQL functionality.
 |
 |  A SQLContext can be used create :class:`DataFrame`, register :clas
s:`DataFrame` as
 |  tables, execute SQL over tables, cache tables, and read parquet fil
es.
 |
 |  :param sparkContext: The :class:`SparkContext` backing this SQLCont
ext.
 |  :param sqlContext: An optional JVM Scala SQLContext. If set, we do
 not instantiate a new
 |      SQLContext in the JVM, instead we make all calls to this objec
t.
 |
 |  Methods defined here:
 |
 |  __init__(self, sparkContext, sqlContext=None)
 |      Creates a new SQLContext.
 |
 |      >>> from datetime import datetime
 |      >>> sqlContext = SQLContext(sc)
 |      >>> allTypes = sc.parallelize([Row(i=1, s="string", d=1.0, l=1,
 |      ...     b=True, list=[1, 2, 3], dict={"s": 0}, row=Row(a=1),
 |      ...     time=datetime(2014, 8, 1, 14, 1, 5))])
 |      >>> df = allTypes.toDF()
 |      >>> df.registerTempTable("allTypes")
 |      >>> sqlContext.sql('select i+1, d+1, not b, list[1], dict["s"],
time, row.a '
 |      ...            'from allTypes where b and i > 0').collect()
 |      [Row(_c0=2, _c1=2.0, _c2=False, _c3=2, _c4=0,            time=
datetime.datetime(2014, 8, 1, 14, 1, 5), a=1)]
 |      >>> df.map(lambda x: (x.i, x.s, x.d, x.l, x.b, x.time, x.row.a,
x.list)).collect()
 |      [(1, u'string', 1.0, 1, True, datetime.datetime(2014, 8, 1, 14,
1, 5), 1, [1, 2, 3])]
 |
 |  applySchema(self, rdd, schema)
 |      .. note:: Deprecated in 1.3, use :func:`createDataFrame` instea
d.
 |
 |  cacheTable(self, tableName)
 |      Caches the specified table in-memory.
 |
 |      .. versionadded:: 1.0
 |
 |  clearCache(self)
 |      Removes all cached tables from the in-memory cache.
 |
 |      .. versionadded:: 1.3
 |
 |  createDataFrame(self, data, schema=None, samplingRatio=None)
 |      Creates a :class:`DataFrame` from an :class:`RDD` of :class:`tu
ple`/:class:`list`,
 |      list or :class:`pandas.DataFrame`.
```

```
 |
 |      When ``schema`` is a list of column names, the type of each col
umn
 |      will be inferred from ``data``.
 |
 |      When ``schema`` is ``None``, it will try to infer the schema (c
olumn names and types)
 |      from ``data``, which should be an RDD of :class:`Row`,
 |      or :class:`namedtuple`, or :class:`dict`.
 |
 |      If schema inference is needed, ``samplingRatio`` is used to det
ermined the ratio of
 |      rows used for schema inference. The first row will be used if `
`samplingRatio`` is ``None``.
 |
 |      :param data: an RDD of :class:`Row`/:class:`tuple`/:class:`list
`/:class:`dict`,
 |          :class:`list`, or :class:`pandas.DataFrame`.
 |      :param schema: a :class:`StructType` or list of column names. d
efault None.
 |      :param samplingRatio: the sample ratio of rows used for inferri
ng
 |      :return: :class:`DataFrame`
 |
 |      >>> l = [('Alice', 1)]
 |      >>> sqlContext.createDataFrame(l).collect()
 |      [Row(_1=u'Alice', _2=1)]
 |      >>> sqlContext.createDataFrame(l, ['name', 'age']).collect()
 |      [Row(name=u'Alice', age=1)]
 |
 |      >>> d = [{'name': 'Alice', 'age': 1}]
 |      >>> sqlContext.createDataFrame(d).collect()
 |      [Row(age=1, name=u'Alice')]
 |
 |      >>> rdd = sc.parallelize(l)
 |      >>> sqlContext.createDataFrame(rdd).collect()
 |      [Row(_1=u'Alice', _2=1)]
 |      >>> df = sqlContext.createDataFrame(rdd, ['name', 'age'])
 |      >>> df.collect()
 |      [Row(name=u'Alice', age=1)]
 |
 |      >>> from pyspark.sql import Row
 |      >>> Person = Row('name', 'age')
 |      >>> person = rdd.map(lambda r: Person(*r))
 |      >>> df2 = sqlContext.createDataFrame(person)
 |      >>> df2.collect()
 |      [Row(name=u'Alice', age=1)]
 |
 |      >>> from pyspark.sql.types import *
 |      >>> schema = StructType([
 |      ...    StructField("name", StringType(), True),
 |      ...    StructField("age", IntegerType(), True)])
 |      >>> df3 = sqlContext.createDataFrame(rdd, schema)
 |      >>> df3.collect()
 |      [Row(name=u'Alice', age=1)]
 |
 |      >>> sqlContext.createDataFrame(df.toPandas()).collect()  # doct
```

```
est: +SKIP
 |      [Row(name=u'Alice', age=1)]
 |      >>> sqlContext.createDataFrame(pandas.DataFrame([[1, 2]]).colle
ct())  # doctest: +SKIP
 |      [Row(0=1, 1=2)]
 |
 |      .. versionadded:: 1.3
 |
 |  createExternalTable(self, tableName, path=None, source=None, schema
=None, **options)
 |      Creates an external table based on the dataset in a data sourc
e.
 |
 |      It returns the DataFrame associated with the external table.
 |
 |      The data source is specified by the ``source`` and a set of ``o
ptions``.
 |      If ``source`` is not specified, the default data source configu
red by
 |      ``spark.sql.sources.default`` will be used.
 |
 |      Optionally, a schema can be provided as the schema of the retur
ned :class:`DataFrame` and
 |      created external table.
 |
 |      :return: :class:`DataFrame`
 |
 |      .. versionadded:: 1.3
 |
 |  getConf(self, key, defaultValue)
 |      Returns the value of Spark SQL configuration property for the g
iven key.
 |
 |      If the key is not set, returns defaultValue.
 |
 |      .. versionadded:: 1.3
 |
 |  inferSchema(self, rdd, samplingRatio=None)
 |      .. note:: Deprecated in 1.3, use :func:`createDataFrame` instea
d.
 |
 |  jsonFile(self, path, schema=None, samplingRatio=1.0)
 |      Loads a text file storing one JSON object per line as a :class:
`DataFrame`.
 |
 |      .. note:: Deprecated in 1.4, use :func:`DataFrameReader.json` i
nstead.
 |
 |      >>> sqlContext.jsonFile('python/test_support/sql/people.json').
dtypes
 |      [('age', 'bigint'), ('name', 'string')]
 |
 |  jsonRDD(self, rdd, schema=None, samplingRatio=1.0)
 |      Loads an RDD storing one JSON object per string as a :class:`Da
taFrame`.
 |
 |      If the schema is provided, applies the given schema to this JSO
```

```
N dataset.
 |      Otherwise, it samples the dataset with ratio ``samplingRatio``
 to determine the schema.
 |
 |      >>> df1 = sqlContext.jsonRDD(json)
 |      >>> df1.first()
 |      Row(field1=1, field2=u'row1', field3=Row(field4=11, field5=Non
e), field6=None)
 |
 |      >>> df2 = sqlContext.jsonRDD(json, df1.schema)
 |      >>> df2.first()
 |      Row(field1=1, field2=u'row1', field3=Row(field4=11, field5=Non
e), field6=None)
 |
 |      >>> from pyspark.sql.types import *
 |      >>> schema = StructType([
 |      ...     StructField("field2", StringType()),
 |      ...     StructField("field3",
 |      ...                 StructType([StructField("field5", ArrayType
(IntegerType()))]))
 |      ... ])
 |      >>> df3 = sqlContext.jsonRDD(json, schema)
 |      >>> df3.first()
 |      Row(field2=u'row1', field3=Row(field5=None))
 |
 |      .. versionadded:: 1.0
 |
 |  load(self, path=None, source=None, schema=None, **options)
 |      Returns the dataset in a data source as a :class:`DataFrame`.
 |
 |      .. note:: Deprecated in 1.4, use :func:`DataFrameReader.load` i
nstead.
 |
 |  parquetFile(self, *paths)
 |      Loads a Parquet file, returning the result as a :class:`DataFra
me`.
 |
 |      .. note:: Deprecated in 1.4, use :func:`DataFrameReader.parquet
` instead.
 |
 |      >>> sqlContext.parquetFile('python/test_support/sql/parquet_par
titioned').dtypes
 |      [('name', 'string'), ('year', 'int'), ('month', 'int'), ('day',
'int')]
 |
 |  range(self, start, end=None, step=1, numPartitions=None)
 |      Create a :class:`DataFrame` with single LongType column named `
id`,
 |      containing elements in a range from `start` to `end` (exclusiv
e) with
 |      step value `step`.
 |
 |      :param start: the start value
 |      :param end: the end value (exclusive)
 |      :param step: the incremental step (default: 1)
 |      :param numPartitions: the number of partitions of the DataFrame
 |      :return: :class:`DataFrame`
```

```
 |
 |      >>> sqlContext.range(1, 7, 2).collect()
 |      [Row(id=1), Row(id=3), Row(id=5)]
 |
 |      If only one argument is specified, it will be used as the end v
alue.
 |
 |      >>> sqlContext.range(3).collect()
 |      [Row(id=0), Row(id=1), Row(id=2)]
 |
 |      .. versionadded:: 1.4
 |
 |  registerDataFrameAsTable(self, df, tableName)
 |      Registers the given :class:`DataFrame` as a temporary table in
 the catalog.
 |
 |      Temporary tables exist only during the lifetime of this instanc
e of :class:`SQLContext`.
 |
 |      >>> sqlContext.registerDataFrameAsTable(df, "table1")
 |
 |      .. versionadded:: 1.3
 |
 |  registerFunction(self, name, f, returnType=StringType)
 |      Registers a lambda function as a UDF so it can be used in SQL s
tatements.
 |
 |      In addition to a name and the function itself, the return type
 can be optionally specified.
 |      When the return type is not given it default to a string and co
nversion will automatically
 |      be done.  For any other return type, the produced object must m
atch the specified type.
 |
 |      :param name: name of the UDF
 |      :param samplingRatio: lambda function
 |      :param returnType: a :class:`DataType` object
 |
 |      >>> sqlContext.registerFunction("stringLengthString", lambda x:
len(x))
 |      >>> sqlContext.sql("SELECT stringLengthString('test')").collect
()
 |      [Row(_c0=u'4')]
 |
 |      >>> from pyspark.sql.types import IntegerType
 |      >>> sqlContext.registerFunction("stringLengthInt", lambda x: le
n(x), IntegerType())
 |      >>> sqlContext.sql("SELECT stringLengthInt('test')").collect()
 |      [Row(_c0=4)]
 |
 |      >>> from pyspark.sql.types import IntegerType
 |      >>> sqlContext.udf.register("stringLengthInt", lambda x: len
(x), IntegerType())
 |      >>> sqlContext.sql("SELECT stringLengthInt('test')").collect()
 |      [Row(_c0=4)]
 |
 |      .. versionadded:: 1.2
```

```
 |
 |  setConf(self, key, value)
 |      Sets the given Spark SQL configuration property.
 |
 |      .. versionadded:: 1.3
 |
 |  sql(self, sqlQuery)
 |      Returns a :class:`DataFrame` representing the result of the giv
en query.
 |
 |      :return: :class:`DataFrame`
 |
 |      >>> sqlContext.registerDataFrameAsTable(df, "table1")
 |      >>> df2 = sqlContext.sql("SELECT field1 AS f1, field2 as f2 fro
m table1")
 |      >>> df2.collect()
 |      [Row(f1=1, f2=u'row1'), Row(f1=2, f2=u'row2'), Row(f1=3, f2=u'r
ow3')]
 |
 |      .. versionadded:: 1.0
 |
 |  table(self, tableName)
 |      Returns the specified table as a :class:`DataFrame`.
 |
 |      :return: :class:`DataFrame`
 |
 |      >>> sqlContext.registerDataFrameAsTable(df, "table1")
 |      >>> df2 = sqlContext.table("table1")
 |      >>> sorted(df.collect()) == sorted(df2.collect())
 |      True
 |
 |      .. versionadded:: 1.0
 |
 |  tableNames(self, dbName=None)
 |      Returns a list of names of tables in the database ``dbName``.
 |
 |      :param dbName: string, name of the database to use. Default to
 the current database.
 |      :return: list of table names, in string
 |
 |      >>> sqlContext.registerDataFrameAsTable(df, "table1")
 |      >>> "table1" in sqlContext.tableNames()
 |      True
 |      >>> "table1" in sqlContext.tableNames("db")
 |      True
 |
 |      .. versionadded:: 1.3
 |
 |  tables(self, dbName=None)
 |      Returns a :class:`DataFrame` containing names of tables in the
 given database.
 |
 |      If ``dbName`` is not specified, the current database will be us
ed.
 |
 |      The returned DataFrame has two columns: ``tableName`` and ``isT
emporary``
```

```
 |      (a column with :class:`BooleanType` indicating if a table is a
 temporary one or not).
 |
 |      :param dbName: string, name of the database to use.
 |      :return: :class:`DataFrame`
 |
 |      >>> sqlContext.registerDataFrameAsTable(df, "table1")
 |      >>> df2 = sqlContext.tables()
 |      >>> df2.filter("tableName = 'table1'").first()
 |      Row(tableName=u'table1', isTemporary=True)
 |
 |      .. versionadded:: 1.3
 |
 |  uncacheTable(self, tableName)
 |      Removes the specified table from the in-memory cache.
 |
 |      .. versionadded:: 1.0
 |
 |  ----------------------------------------------------------------------
---
 |  Data descriptors defined here:
 |
 |  __dict__
 |      dictionary for instance variables (if defined)
 |
 |  __weakref__
 |      list of weak references to the object (if defined)
 |
 |  read
 |      Returns a :class:`DataFrameReader` that can be used to read dat
a
 |      in as a :class:`DataFrame`.
 |
 |      :return: :class:`DataFrameReader`
 |
 |      .. versionadded:: 1.4
 |
 |  udf
 |      Returns a :class:`UDFRegistration` for UDF registration.
 |
 |      :return: :class:`UDFRegistration`
 |
 |      .. versionadded:: 1.3.1
```

Outside of `pyspark` or a notebook, `SQLContext` is created from the lower-level `SparkContext`, which is usually used to create Resilient Distributed Datasets (RDDs). An RDD is the way Spark actually represents data internally; DataFrames are actually implemented in terms of RDDs.

While you can interact directly with RDDs, DataFrames are preferred. They're generally faster, and they perform the same no matter what language (Python, R, Scala or Java) you use with Spark.

In this course, we'll be using DataFrames, so we won't be interacting directly with the Spark Context object very much. However, it's worth knowing that inside `pyspark` or a notebook, you already have an existing `SparkContext` in the `sc` variable. One simple thing we can do with `sc` is check the version of Spark we're using:

In [10]:
```
# After reading the help we've decided we want to use sc.version to see
what version of Spark we are running
sc.version
```

Out[10]:
```
1.5.2
```

In [11]:
```
# Help can be used on any Python object
help(map)
```

```
Help on built-in function map in module __builtin__:

map(...)
    map(function, sequence[, sequence, ...]) -> list

    Return a list of the results of applying the function to the items
 of
    the argument sequence(s).  If more than one sequence is given, the
    function is called with an argument list consisting of the correspo
nding
    item of each sequence, substituting None for missing values when no
t all
    sequences have the same length.  If the function is None, return a
 list of
    the items of the sequence (or a list of tuples if more than one seq
uence).
```

Part 3: Using DataFrames and chaining together transformations and actions

Working with your first DataFrames

In Spark, we first create a base DataFrame (http://spark.apache.org/docs/latest/api/python/pyspark.sql.html#pyspark.sql.DataFrame). We can then apply one or more transformations to that base DataFrame. *A DataFrame is immutable, so once it is created, it cannot be changed.* As a result, each transformation creates a new DataFrame. Finally, we can apply one or more actions to the DataFrames.

> Note that Spark uses lazy evaluation, so transformations are not actually executed until an action occurs.

We will perform several exercises to obtain a better understanding of DataFrames:

- Create a Python collection of 10,000 integers
- Create a Spark DataFrame from that collection
- Subtract one from each value using `map`
- Perform action `collect` to view results
- Perform action `count` to view counts
- Apply transformation `filter` and view results with `collect`
- Learn about lambda functions
- Explore how lazy evaluation works and the debugging challenges that it introduces

A DataFrame consists of a series of `Row` objects; each `Row` object has a set of named columns. You can think of a DataFrame as modeling a table, though the data source being processed does not have to be a table.

More formally, a DataFrame must have a *schema*, which means it must consist of columns, each of which has a *name* and a *type*. Some data sources have schemas built into them. Examples include RDBMS databases, Parquet files, and NoSQL databases like Cassandra. Other data sources don't have computer-readable schemas, but you can often apply a schema programmatically.

(3a) Create a Python collection of 10,000 people

We will use a third-party Python testing library called fake-factory (https://pypi.python.org/pypi/fake-factory/0.5.3) to create a collection of fake person records.

From the command line on login1 node, run the following command and restart this kernel:

```
pip install --upgrade fake-factory --user
```

In [12]:
```
from faker import Factory
fake = Factory.create()
fake.seed(4321)
```

We're going to use this factory to create a collection of randomly generated people records. In the next section, we'll turn that collection into a DataFrame. We'll use the Spark `Row` class, because that will help us define the Spark DataFrame schema. There are other ways to define schemas, though; see the Spark Programming Guide's discussion of [schema inference (http://spark.apache.org/docs/latest/sql-programming-guide.html#inferring-the-schema-using-reflection)](http://spark.apache.org/docs/latest/sql-programming-guide.html#inferring-the-schema-using-reflection) for more information. (For instance, we could also use a Python `namedtuple`.)

In [13]:
```
# Each entry consists of last_name, first_name, ssn, job, and age (at le
ast 1)
from pyspark.sql import Row
def fake_entry():
  name = fake.name().split()
  return (name[1], name[0], fake.ssn(), fake.job(), abs(2016 - fake.date
_time().year) + 1)
```

In [14]:
```
# Create a helper function to call a function repeatedly
def repeat(times, func, *args, **kwargs):
    for _ in xrange(times):
        yield func(*args, **kwargs)
```

In [15]:
```
data = list(repeat(10000, fake_entry))
```

`data` is just a normal Python list, containing Python tuples objects. Let's look at the first item in the list:

In [16]:
```
data[0]
```

Out[16]:
```
(u'Brown', u'Jason', u'160-37-9051', 'Agricultural engineer', 39)
```

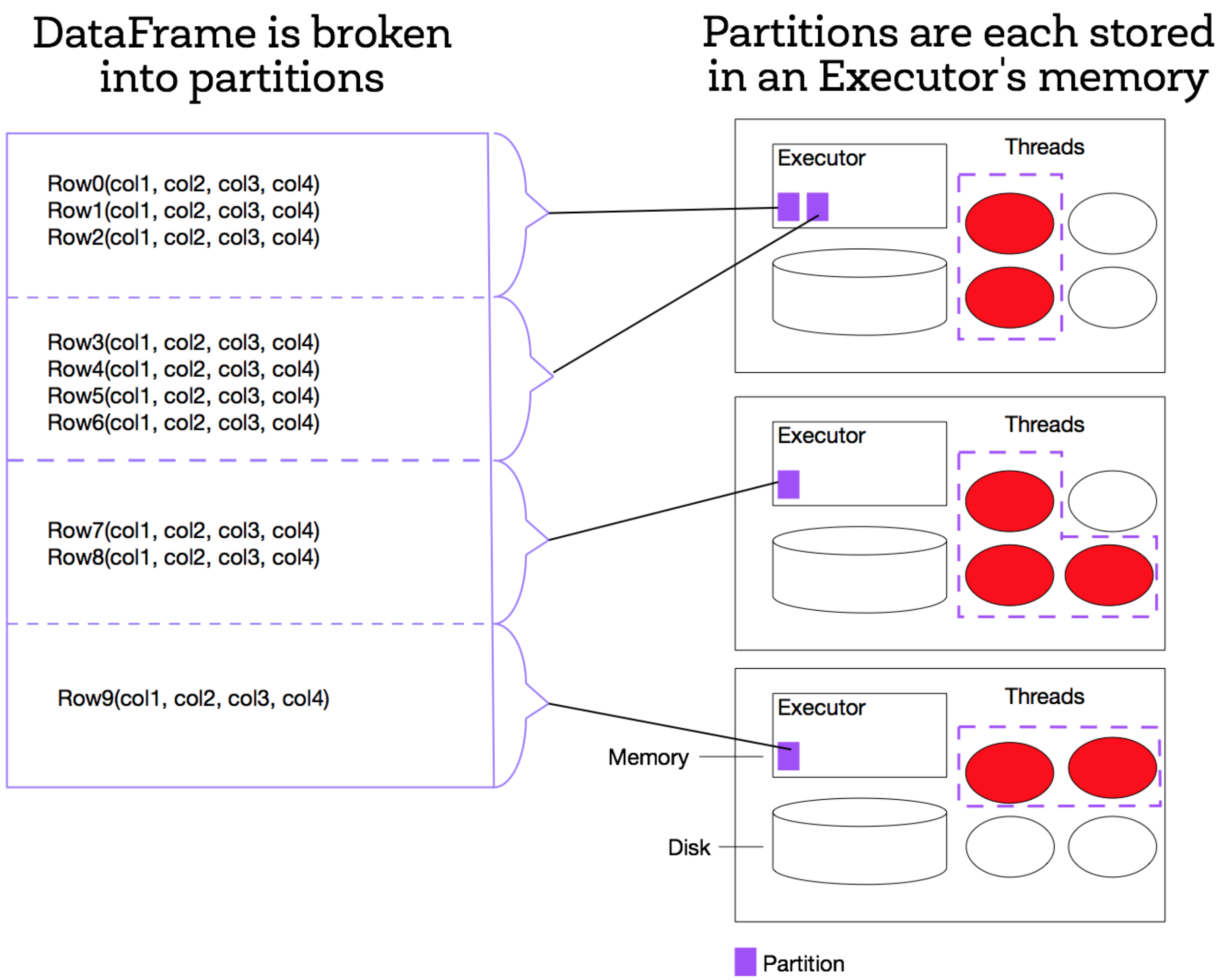
We can check the size of the list using the Python `len()` function.

In [17]:
```
len(data)
```

Out[17]:
```
10000
```

(3b) Distributed data and using a collection to create a DataFrame

In Spark, datasets are represented as a list of entries, where the list is broken up into many different partitions that are each stored on a different machine. Each partition holds a unique subset of the entries in the list. Spark calls datasets that it stores "Resilient Distributed Datasets" (RDDs). Even DataFrames are ultimately represented as RDDs, with additional meta-data.



One of the defining features of Spark, compared to other data analytics frameworks (e.g., Hadoop), is that it stores data in memory rather than on disk. This allows Spark applications to run much more quickly, because they are not slowed down by needing to read data from disk. The figure to the right illustrates how Spark breaks a list of data entries into partitions that are each stored in memory on a worker.

To create the DataFrame, we'll use `sqlContext.createDataFrame()`, and we'll pass our array of data in as an argument to that function. Spark will create a new set of input data based on data that is passed in. A DataFrame requires a *schema*, which is a list of columns, where each column has a name and a type. Our list of data has elements with types (mostly strings, but one integer). We'll supply the rest of the schema and the column names as the second argument to `createDataFrame()`.

Let's view the help for `createDataFrame()`.

In [18]:
```
help(sqlContext.createDataFrame)
```

```
Help on method createDataFrame in module pyspark.sql.context:

createDataFrame(self, data, schema=None, samplingRatio=None) method of
 pyspark.sql.context.SQLContext instance
    Creates a :class:`DataFrame` from an :class:`RDD` of :class:`tuple
`/:class:`list`,
    list or :class:`pandas.DataFrame`.

    When ``schema`` is a list of column names, the type of each column
    will be inferred from ``data``.

    When ``schema`` is ``None``, it will try to infer the schema (colum
n names and types)
    from ``data``, which should be an RDD of :class:`Row`,
    or :class:`namedtuple`, or :class:`dict`.

    If schema inference is needed, ``samplingRatio`` is used to determi
ned the ratio of
    rows used for schema inference. The first row will be used if ``sam
plingRatio`` is ``None``.

    :param data: an RDD of :class:`Row`/:class:`tuple`/:class:`list`/:c
lass:`dict`,
        :class:`list`, or :class:`pandas.DataFrame`.
    :param schema: a :class:`StructType` or list of column names. defau
lt None.
    :param samplingRatio: the sample ratio of rows used for inferring
    :return: :class:`DataFrame`

    >>> l = [('Alice', 1)]
    >>> sqlContext.createDataFrame(l).collect()
    [Row(_1=u'Alice', _2=1)]
    >>> sqlContext.createDataFrame(l, ['name', 'age']).collect()
    [Row(name=u'Alice', age=1)]

    >>> d = [{'name': 'Alice', 'age': 1}]
    >>> sqlContext.createDataFrame(d).collect()
    [Row(age=1, name=u'Alice')]

    >>> rdd = sc.parallelize(l)
    >>> sqlContext.createDataFrame(rdd).collect()
    [Row(_1=u'Alice', _2=1)]
    >>> df = sqlContext.createDataFrame(rdd, ['name', 'age'])
    >>> df.collect()
    [Row(name=u'Alice', age=1)]

    >>> from pyspark.sql import Row
    >>> Person = Row('name', 'age')
    >>> person = rdd.map(lambda r: Person(*r))
    >>> df2 = sqlContext.createDataFrame(person)
    >>> df2.collect()
    [Row(name=u'Alice', age=1)]

    >>> from pyspark.sql.types import *
    >>> schema = StructType([
    ...    StructField("name", StringType(), True),
    ...    StructField("age", IntegerType(), True)])
```

```
    >>> df3 = sqlContext.createDataFrame(rdd, schema)
    >>> df3.collect()
    [Row(name=u'Alice', age=1)]

    >>> sqlContext.createDataFrame(df.toPandas()).collect()  # doctest:
+SKIP
    [Row(name=u'Alice', age=1)]
    >>> sqlContext.createDataFrame(pandas.DataFrame([[1, 2]]).collect
())  # doctest: +SKIP
    [Row(0=1, 1=2)]

    .. versionadded:: 1.3
```

In [19]:
```
dataDF = sqlContext.createDataFrame(data, ('last_name', 'first_name', 'ssn', 'occupation', 'age'))
```

Let's see what type `sqlContext.createDataFrame()` returned.

In [20]:
```
print 'type of dataDF: {0}'.format(type(dataDF))
```

```
type of dataDF: <class 'pyspark.sql.dataframe.DataFrame'>
```

Let's take a look at the DataFrame's schema and some of its rows.

In [21]:
```
dataDF.printSchema()
```

```
root
 |-- last_name: string (nullable = true)
 |-- first_name: string (nullable = true)
 |-- ssn: string (nullable = true)
 |-- occupation: string (nullable = true)
 |-- age: long (nullable = true)
```

We can register the newly created DataFrame as a named table, using the `registerDataFrameAsTable()` method.

In [22]:
```
sqlContext.registerDataFrameAsTable(dataDF, 'dataframe')
```

What methods can we call on this DataFrame?

In [23]:
```
help(dataDF)
```

```
Help on DataFrame in module pyspark.sql.dataframe object:

class DataFrame(__builtin__.object)
 |  A distributed collection of data grouped into named columns.
 |
 |  A :class:`DataFrame` is equivalent to a relational table in Spark S
QL,
 |  and can be created using various functions in :class:`SQLContext`::
 |
 |      people = sqlContext.read.parquet("...")
 |
 |  Once created, it can be manipulated using the various domain-specif
ic-language
 |  (DSL) functions defined in: :class:`DataFrame`, :class:`Column`.
 |
 |  To select a column from the data frame, use the apply method::
 |
 |      ageCol = people.age
 |
 |  A more concrete example::
 |
 |      # To create DataFrame using SQLContext
 |      people = sqlContext.read.parquet("...")
 |      department = sqlContext.read.parquet("...")
 |
 |      people.filter(people.age > 30).join(department, people.deptId =
= department.id))           .groupBy(department.name, "gender").agg({"s
alary": "avg", "age": "max"})
 |
 |  .. note:: Experimental
 |
 |  .. versionadded:: 1.3
 |
 |  Methods defined here:
 |
 |  __getattr__(self, name)
 |      Returns the :class:`Column` denoted by ``name``.
 |
 |      >>> df.select(df.age).collect()
 |      [Row(age=2), Row(age=5)]
 |
 |      .. versionadded:: 1.3
 |
 |  __getitem__(self, item)
 |      Returns the column as a :class:`Column`.
 |
 |      >>> df.select(df['age']).collect()
 |      [Row(age=2), Row(age=5)]
 |      >>> df[ ["name", "age"]].collect()
 |      [Row(name=u'Alice', age=2), Row(name=u'Bob', age=5)]
 |      >>> df[ df.age > 3 ].collect()
 |      [Row(age=5, name=u'Bob')]
 |      >>> df[df[0] > 3].collect()
 |      [Row(age=5, name=u'Bob')]
 |
 |      .. versionadded:: 1.3
 |
```

```
 |  __init__(self, jdf, sql_ctx)
 |
 |  __repr__(self)
 |
 |  agg(self, *exprs)
 |      Aggregate on the entire :class:`DataFrame` without groups
 |      (shorthand for ``df.groupBy.agg()``).
 |
 |      >>> df.agg({"age": "max"}).collect()
 |      [Row(max(age)=5)]
 |      >>> from pyspark.sql import functions as F
 |      >>> df.agg(F.min(df.age)).collect()
 |      [Row(min(age)=2)]
 |
 |      .. versionadded:: 1.3
 |
 |  alias(self, alias)
 |      Returns a new :class:`DataFrame` with an alias set.
 |
 |      >>> from pyspark.sql.functions import *
 |      >>> df_as1 = df.alias("df_as1")
 |      >>> df_as2 = df.alias("df_as2")
 |      >>> joined_df = df_as1.join(df_as2, col("df_as1.name") == col
("df_as2.name"), 'inner')
 |      >>> joined_df.select(col("df_as1.name"), col("df_as2.name"), co
l("df_as2.age")).collect()
 |      [Row(name=u'Alice', name=u'Alice', age=2), Row(name=u'Bob', nam
e=u'Bob', age=5)]
 |
 |      .. versionadded:: 1.3
 |
 |  cache(self)
 |      Persists with the default storage level (C{MEMORY_ONLY_SER}).
 |
 |      .. versionadded:: 1.3
 |
 |  coalesce(self, numPartitions)
 |      Returns a new :class:`DataFrame` that has exactly `numPartition
s` partitions.
 |
 |      Similar to coalesce defined on an :class:`RDD`, this operation
 results in a
 |      narrow dependency, e.g. if you go from 1000 partitions to 100 p
artitions,
 |      there will not be a shuffle, instead each of the 100 new partit
ions will
 |      claim 10 of the current partitions.
 |
 |      >>> df.coalesce(1).rdd.getNumPartitions()
 |      1
 |
 |      .. versionadded:: 1.4
 |
 |  collect(self)
 |      Returns all the records as a list of :class:`Row`.
 |
 |      >>> df.collect()
```

```
 |      [Row(age=2, name=u'Alice'), Row(age=5, name=u'Bob')]
 |
 |      .. versionadded:: 1.3
 |
 |  corr(self, col1, col2, method=None)
 |      Calculates the correlation of two columns of a DataFrame as a d
ouble value.
 |      Currently only supports the Pearson Correlation Coefficient.
 |      :func:`DataFrame.corr` and :func:`DataFrameStatFunctions.corr`
 are aliases of each other.
 |
 |      :param col1: The name of the first column
 |      :param col2: The name of the second column
 |      :param method: The correlation method. Currently only supports
 "pearson"
 |
 |      .. versionadded:: 1.4
 |
 |  count(self)
 |      Returns the number of rows in this :class:`DataFrame`.
 |
 |      >>> df.count()
 |      2
 |
 |      .. versionadded:: 1.3
 |
 |  cov(self, col1, col2)
 |      Calculate the sample covariance for the given columns, specifie
d by their names, as a
 |      double value. :func:`DataFrame.cov` and :func:`DataFrameStatFun
ctions.cov` are aliases.
 |
 |      :param col1: The name of the first column
 |      :param col2: The name of the second column
 |
 |      .. versionadded:: 1.4
 |
 |  crosstab(self, col1, col2)
 |      Computes a pair-wise frequency table of the given columns. Also
known as a contingency
 |      table. The number of distinct values for each column should be
 less than 1e4. At most 1e6
 |      non-zero pair frequencies will be returned.
 |      The first column of each row will be the distinct values of `co
l1` and the column names
 |      will be the distinct values of `col2`. The name of the first co
lumn will be `$col1_$col2`.
 |      Pairs that have no occurrences will have zero as their counts.
 |      :func:`DataFrame.crosstab` and :func:`DataFrameStatFunctions.cr
osstab` are aliases.
 |
 |      :param col1: The name of the first column. Distinct items will
 make the first item of
 |          each row.
 |      :param col2: The name of the second column. Distinct items will
make the column names
 |          of the DataFrame.
```

```
 |
 |      .. versionadded:: 1.4
 |
 |  cube(self, *cols)
 |      Create a multi-dimensional cube for the current :class:`DataFra
me` using
 |      the specified columns, so we can run aggregation on them.
 |
 |      >>> df.cube('name', df.age).count().show()
 |      +-----+----+-----+
 |      | name| age|count|
 |      +-----+----+-----+
 |      | null|   2|    1|
 |      |Alice|null|    1|
 |      |  Bob|   5|    1|
 |      |  Bob|null|    1|
 |      | null|   5|    1|
 |      | null|null|    2|
 |      |Alice|   2|    1|
 |      +-----+----+-----+
 |
 |      .. versionadded:: 1.4
 |
 |  describe(self, *cols)
 |      Computes statistics for numeric columns.
 |
 |      This include count, mean, stddev, min, and max. If no columns a
re
 |      given, this function computes statistics for all numerical colu
mns.
 |
 |      .. note:: This function is meant for exploratory data analysis,
as we make no         guarantee about the backward compatibility of the
schema of the resulting DataFrame.
 |
 |      >>> df.describe().show()
 |      +-------+---+
 |      |summary|age|
 |      +-------+---+
 |      |  count|  2|
 |      |   mean|3.5|
 |      | stddev|1.5|
 |      |    min|  2|
 |      |    max|  5|
 |      +-------+---+
 |      >>> df.describe(['age', 'name']).show()
 |      +-------+---+-----+
 |      |summary|age| name|
 |      +-------+---+-----+
 |      |  count|  2|    2|
 |      |   mean|3.5| null|
 |      | stddev|1.5| null|
 |      |    min|  2|Alice|
 |      |    max|  5|  Bob|
 |      +-------+---+-----+
 |
 |      .. versionadded:: 1.3.1
```

```
 |
 |  distinct(self)
 |      Returns a new :class:`DataFrame` containing the distinct rows i
n this :class:`DataFrame`.
 |
 |      >>> df.distinct().count()
 |      2
 |
 |      .. versionadded:: 1.3
 |
 |  drop(self, col)
 |      Returns a new :class:`DataFrame` that drops the specified colum
n.
 |
 |      :param col: a string name of the column to drop, or a
 |          :class:`Column` to drop.
 |
 |      >>> df.drop('age').collect()
 |      [Row(name=u'Alice'), Row(name=u'Bob')]
 |
 |      >>> df.drop(df.age).collect()
 |      [Row(name=u'Alice'), Row(name=u'Bob')]
 |
 |      >>> df.join(df2, df.name == df2.name, 'inner').drop(df.name).co
llect()
 |      [Row(age=5, height=85, name=u'Bob')]
 |
 |      >>> df.join(df2, df.name == df2.name, 'inner').drop(df2.name).c
ollect()
 |      [Row(age=5, name=u'Bob', height=85)]
 |
 |      .. versionadded:: 1.4
 |
 |  dropDuplicates(self, subset=None)
 |      Return a new :class:`DataFrame` with duplicate rows removed,
 |      optionally only considering certain columns.
 |
 |      >>> from pyspark.sql import Row
 |      >>> df = sc.parallelize([             Row(name='Alice', age=5,
 height=80),             Row(name='Alice', age=5, height=80),
   Row(name='Alice', age=10, height=80)]).toDF()
 |      >>> df.dropDuplicates().show()
 |      +---+------+-----+
 |      |age|height| name|
 |      +---+------+-----+
 |      |  5|    80|Alice|
 |      | 10|    80|Alice|
 |      +---+------+-----+
 |
 |      >>> df.dropDuplicates(['name', 'height']).show()
 |      +---+------+-----+
 |      |age|height| name|
 |      +---+------+-----+
 |      |  5|    80|Alice|
 |      +---+------+-----+
 |
 |      .. versionadded:: 1.4
```

```
 |
 |  drop_duplicates = dropDuplicates(self, subset=None)
 |
 |  dropna(self, how='any', thresh=None, subset=None)
 |      Returns a new :class:`DataFrame` omitting rows with null value
s.
 |      :func:`DataFrame.dropna` and :func:`DataFrameNaFunctions.drop`
 are aliases of each other.
 |
 |      :param how: 'any' or 'all'.
 |          If 'any', drop a row if it contains any nulls.
 |          If 'all', drop a row only if all its values are null.
 |      :param thresh: int, default None
 |          If specified, drop rows that have less than `thresh` non-nu
ll values.
 |          This overwrites the `how` parameter.
 |      :param subset: optional list of column names to consider.
 |
 |      >>> df4.na.drop().show()
 |      +---+------+-----+
 |      |age|height| name|
 |      +---+------+-----+
 |      | 10|    80|Alice|
 |      +---+------+-----+
 |
 |      .. versionadded:: 1.3.1
 |
 |  explain(self, extended=False)
 |      Prints the (logical and physical) plans to the console for debu
gging purpose.
 |
 |      :param extended: boolean, default ``False``. If ``False``, prin
ts only the physical plan.
 |
 |      >>> df.explain()
 |      Scan PhysicalRDD[age#0,name#1]
 |
 |      >>> df.explain(True)
 |      == Parsed Logical Plan ==
 |      ...
 |      == Analyzed Logical Plan ==
 |      ...
 |      == Optimized Logical Plan ==
 |      ...
 |      == Physical Plan ==
 |      ...
 |
 |      .. versionadded:: 1.3
 |
 |  fillna(self, value, subset=None)
 |      Replace null values, alias for ``na.fill()``.
 |      :func:`DataFrame.fillna` and :func:`DataFrameNaFunctions.fill`
 are aliases of each other.
 |
 |      :param value: int, long, float, string, or dict.
 |          Value to replace null values with.
 |          If the value is a dict, then `subset` is ignored and `value
```

```
` must be a mapping
 |          from column name (string) to replacement value. The replace
ment value must be
 |          an int, long, float, or string.
 |      :param subset: optional list of column names to consider.
 |          Columns specified in subset that do not have matching data
 type are ignored.
 |          For example, if `value` is a string, and subset contains a
 non-string column,
 |          then the non-string column is simply ignored.
 |
 |      >>> df4.na.fill(50).show()
 |      +---+------+-----+
 |      |age|height| name|
 |      +---+------+-----+
 |      | 10|    80|Alice|
 |      |  5|    50|  Bob|
 |      | 50|    50|  Tom|
 |      | 50|    50| null|
 |      +---+------+-----+
 |
 |      >>> df4.na.fill({'age': 50, 'name': 'unknown'}).show()
 |      +---+------+-------+
 |      |age|height|   name|
 |      +---+------+-------+
 |      | 10|    80|  Alice|
 |      |  5|  null|    Bob|
 |      | 50|  null|    Tom|
 |      | 50|  null|unknown|
 |      +---+------+-------+
 |
 |      .. versionadded:: 1.3.1
 |
 |  filter(self, condition)
 |      Filters rows using the given condition.
 |
 |      :func:`where` is an alias for :func:`filter`.
 |
 |      :param condition: a :class:`Column` of :class:`types.BooleanTyp
e`
 |          or a string of SQL expression.
 |
 |      >>> df.filter(df.age > 3).collect()
 |      [Row(age=5, name=u'Bob')]
 |      >>> df.where(df.age == 2).collect()
 |      [Row(age=2, name=u'Alice')]
 |
 |      >>> df.filter("age > 3").collect()
 |      [Row(age=5, name=u'Bob')]
 |      >>> df.where("age = 2").collect()
 |      [Row(age=2, name=u'Alice')]
 |
 |      .. versionadded:: 1.3
 |
 |  first(self)
 |      Returns the first row as a :class:`Row`.
 |
```

```
 |      >>> df.first()
 |      Row(age=2, name=u'Alice')
 |
 |      .. versionadded:: 1.3
 |
 |  flatMap(self, f)
 |      Returns a new :class:`RDD` by first applying the ``f`` function
to each :class:`Row`,
 |      and then flattening the results.
 |
 |      This is a shorthand for ``df.rdd.flatMap()``.
 |
 |      >>> df.flatMap(lambda p: p.name).collect()
 |      [u'A', u'l', u'i', u'c', u'e', u'B', u'o', u'b']
 |
 |      .. versionadded:: 1.3
 |
 |  foreach(self, f)
 |      Applies the ``f`` function to all :class:`Row` of this :class:`
DataFrame`.
 |
 |      This is a shorthand for ``df.rdd.foreach()``.
 |
 |      >>> def f(person):
 |      ...     print(person.name)
 |      >>> df.foreach(f)
 |
 |      .. versionadded:: 1.3
 |
 |  foreachPartition(self, f)
 |      Applies the ``f`` function to each partition of this :class:`Da
taFrame`.
 |
 |      This a shorthand for ``df.rdd.foreachPartition()``.
 |
 |      >>> def f(people):
 |      ...     for person in people:
 |      ...         print(person.name)
 |      >>> df.foreachPartition(f)
 |
 |      .. versionadded:: 1.3
 |
 |  freqItems(self, cols, support=None)
 |      Finding frequent items for columns, possibly with false positiv
es. Using the
 |      frequent element count algorithm described in
 |      "http://dx.doi.org/10.1145/762471.762473, proposed by Karp, Sch
enker, and Papadimitriou".
 |      :func:`DataFrame.freqItems` and :func:`DataFrameStatFunctions.f
reqItems` are aliases.
 |
 |      .. note::  This function is meant for exploratory data analysi
s, as we make no         guarantee about the backward compatibility of
 the schema of the resulting DataFrame.
 |
 |      :param cols: Names of the columns to calculate frequent items f
or as a list or tuple of
```

```
 |          strings.
 |      :param support: The frequency with which to consider an item 'f
requent'. Default is 1%.
 |          The support must be greater than 1e-4.
 |
 |      .. versionadded:: 1.4
 |
 |  groupBy(self, *cols)
 |      Groups the :class:`DataFrame` using the specified columns,
 |      so we can run aggregation on them. See :class:`GroupedData`
 |      for all the available aggregate functions.
 |
 |      :func:`groupby` is an alias for :func:`groupBy`.
 |
 |      :param cols: list of columns to group by.
 |          Each element should be a column name (string) or an express
ion (:class:`Column`).
 |
 |      >>> df.groupBy().avg().collect()
 |      [Row(avg(age)=3.5)]
 |      >>> df.groupBy('name').agg({'age': 'mean'}).collect()
 |      [Row(name=u'Alice', avg(age)=2.0), Row(name=u'Bob', avg(age)=5.
0)]
 |      >>> df.groupBy(df.name).avg().collect()
 |      [Row(name=u'Alice', avg(age)=2.0), Row(name=u'Bob', avg(age)=5.
0)]
 |      >>> df.groupBy(['name', df.age]).count().collect()
 |      [Row(name=u'Bob', age=5, count=1), Row(name=u'Alice', age=2, co
unt=1)]
 |
 |      .. versionadded:: 1.3
 |
 |  groupby = groupBy(self, *cols)
 |
 |  head(self, n=None)
 |      Returns the first ``n`` rows.
 |
 |      :param n: int, default 1. Number of rows to return.
 |      :return: If n is greater than 1, return a list of :class:`Row`.
 |          If n is 1, return a single Row.
 |
 |      >>> df.head()
 |      Row(age=2, name=u'Alice')
 |      >>> df.head(1)
 |      [Row(age=2, name=u'Alice')]
 |
 |      .. versionadded:: 1.3
 |
 |  insertInto(self, tableName, overwrite=False)
 |      Inserts the contents of this :class:`DataFrame` into the specif
ied table.
 |
 |      .. note:: Deprecated in 1.4, use :func:`DataFrameWriter.insertI
nto` instead.
 |
 |  intersect(self, other)
 |      Return a new :class:`DataFrame` containing rows only in
```

```
 |      both this frame and another frame.
 |
 |      This is equivalent to `INTERSECT` in SQL.
 |
 |      .. versionadded:: 1.3
 |
 |  isLocal(self)
 |      Returns ``True`` if the :func:`collect` and :func:`take` method
s can be run locally
 |      (without any Spark executors).
 |
 |      .. versionadded:: 1.3
 |
 |  join(self, other, on=None, how=None)
 |      Joins with another :class:`DataFrame`, using the given join exp
ression.
 |
 |      The following performs a full outer join between ``df1`` and ``
df2``.
 |
 |      :param other: Right side of the join
 |      :param on: a string for join column name, a list of column name
s,
 |          , a join expression (Column) or a list of Columns.
 |          If `on` is a string or a list of string indicating the name
of the join column(s),
 |          the column(s) must exist on both sides, and this performs a
n inner equi-join.
 |      :param how: str, default 'inner'.
 |          One of `inner`, `outer`, `left_outer`, `right_outer`, `semi
join`.
 |
 |      >>> df.join(df2, df.name == df2.name, 'outer').select(df.name,
 df2.height).collect()
 |      [Row(name=None, height=80), Row(name=u'Alice', height=None), Ro
w(name=u'Bob', height=85)]
 |
 |      >>> cond = [df.name == df3.name, df.age == df3.age]
 |      >>> df.join(df3, cond, 'outer').select(df.name, df3.age).collec
t()
 |      [Row(name=u'Bob', age=5), Row(name=u'Alice', age=2)]
 |
 |      >>> df.join(df2, 'name').select(df.name, df2.height).collect()
 |      [Row(name=u'Bob', height=85)]
 |
 |      >>> df.join(df4, ['name', 'age']).select(df.name, df.age).colle
ct()
 |      [Row(name=u'Bob', age=5)]
 |
 |      .. versionadded:: 1.3
 |
 |  limit(self, num)
 |      Limits the result count to the number specified.
 |
 |      >>> df.limit(1).collect()
 |      [Row(age=2, name=u'Alice')]
 |      >>> df.limit(0).collect()
```

```
 |      []
 |
 |      .. versionadded:: 1.3
 |
 |  map(self, f)
 |      Returns a new :class:`RDD` by applying a the ``f`` function to
 each :class:`Row`.
 |
 |      This is a shorthand for ``df.rdd.map()``.
 |
 |      >>> df.map(lambda p: p.name).collect()
 |      [u'Alice', u'Bob']
 |
 |      .. versionadded:: 1.3
 |
 |  mapPartitions(self, f, preservesPartitioning=False)
 |      Returns a new :class:`RDD` by applying the ``f`` function to ea
ch partition.
 |
 |      This is a shorthand for ``df.rdd.mapPartitions()``.
 |
 |      >>> rdd = sc.parallelize([1, 2, 3, 4], 4)
 |      >>> def f(iterator): yield 1
 |      >>> rdd.mapPartitions(f).sum()
 |      4
 |
 |      .. versionadded:: 1.3
 |
 |  orderBy = sort(self, *cols, **kwargs)
 |
 |  persist(self, storageLevel=StorageLevel(False, True, False, False,
 1))
 |      Sets the storage level to persist its values across operations
 |      after the first time it is computed. This can only be used to a
ssign
 |      a new storage level if the RDD does not have a storage level se
t yet.
 |      If no storage level is specified defaults to (C{MEMORY_ONLY_SE
R}).
 |
 |      .. versionadded:: 1.3
 |
 |  printSchema(self)
 |      Prints out the schema in the tree format.
 |
 |      >>> df.printSchema()
 |      root
 |       |-- age: integer (nullable = true)
 |       |-- name: string (nullable = true)
 |      <BLANKLINE>
 |
 |      .. versionadded:: 1.3
 |
 |  randomSplit(self, weights, seed=None)
 |      Randomly splits this :class:`DataFrame` with the provided weigh
ts.
 |
```

```
 |      :param weights: list of doubles as weights with which to split
 the DataFrame. Weights will
 |          be normalized if they don't sum up to 1.0.
 |      :param seed: The seed for sampling.
 |
 |      >>> splits = df4.randomSplit([1.0, 2.0], 24)
 |      >>> splits[0].count()
 |      1
 |
 |      >>> splits[1].count()
 |      3
 |
 |      .. versionadded:: 1.4
 |
 |  registerAsTable(self, name)
 |      .. note:: Deprecated in 1.4, use :func:`registerTempTable` inst
ead.
 |
 |  registerTempTable(self, name)
 |      Registers this RDD as a temporary table using the given name.
 |
 |      The lifetime of this temporary table is tied to the :class:`SQL
Context`
 |      that was used to create this :class:`DataFrame`.
 |
 |      >>> df.registerTempTable("people")
 |      >>> df2 = sqlContext.sql("select * from people")
 |      >>> sorted(df.collect()) == sorted(df2.collect())
 |      True
 |
 |      .. versionadded:: 1.3
 |
 |  repartition(self, numPartitions)
 |      Returns a new :class:`DataFrame` that has exactly ``numPartitio
ns`` partitions.
 |
 |      >>> df.repartition(10).rdd.getNumPartitions()
 |      10
 |
 |      .. versionadded:: 1.3
 |
 |  replace(self, to_replace, value, subset=None)
 |      Returns a new :class:`DataFrame` replacing a value with another
value.
 |      :func:`DataFrame.replace` and :func:`DataFrameNaFunctions.repla
ce` are
 |      aliases of each other.
 |
 |      :param to_replace: int, long, float, string, or list.
 |          Value to be replaced.
 |          If the value is a dict, then `value` is ignored and `to_rep
lace` must be a
 |          mapping from column name (string) to replacement value. The
value to be
 |          replaced must be an int, long, float, or string.
 |      :param value: int, long, float, string, or list.
 |          Value to use to replace holes.
```

```
 |          The replacement value must be an int, long, float, or strin
g. If `value` is a
 |          list or tuple, `value` should be of the same length with `t
o_replace`.
 |      :param subset: optional list of column names to consider.
 |          Columns specified in subset that do not have matching data
 type are ignored.
 |          For example, if `value` is a string, and subset contains a
 non-string column,
 |          then the non-string column is simply ignored.
 |
 |      >>> df4.na.replace(10, 20).show()
 |      +----+------+-----+
 |      | age|height| name|
 |      +----+------+-----+
 |      |  20|    80|Alice|
 |      |   5|  null|  Bob|
 |      |null|  null|  Tom|
 |      |null|  null| null|
 |      +----+------+-----+
 |
 |      >>> df4.na.replace(['Alice', 'Bob'], ['A', 'B'], 'name').show()
 |      +----+------+----+
 |      | age|height|name|
 |      +----+------+----+
 |      |  10|    80|   A|
 |      |   5|  null|   B|
 |      |null|  null| Tom|
 |      |null|  null|null|
 |      +----+------+----+
 |
 |      .. versionadded:: 1.4
 |
 |  rollup(self, *cols)
 |      Create a multi-dimensional rollup for the current :class:`DataF
rame` using
 |      the specified columns, so we can run aggregation on them.
 |
 |      >>> df.rollup('name', df.age).count().show()
 |      +-----+----+-----+
 |      | name| age|count|
 |      +-----+----+-----+
 |      |Alice|null|    1|
 |      |  Bob|   5|    1|
 |      |  Bob|null|    1|
 |      | null|null|    2|
 |      |Alice|   2|    1|
 |      +-----+----+-----+
 |
 |      .. versionadded:: 1.4
 |
 |  sample(self, withReplacement, fraction, seed=None)
 |      Returns a sampled subset of this :class:`DataFrame`.
 |
 |      >>> df.sample(False, 0.5, 42).count()
 |      1
 |
```

```
 |      .. versionadded:: 1.3
 |
 |  sampleBy(self, col, fractions, seed=None)
 |      Returns a stratified sample without replacement based on the
 |      fraction given on each stratum.
 |
 |      :param col: column that defines strata
 |      :param fractions:
 |          sampling fraction for each stratum. If a stratum is not
 |          specified, we treat its fraction as zero.
 |      :param seed: random seed
 |      :return: a new DataFrame that represents the stratified sample
 |
 |      >>> from pyspark.sql.functions import col
 |      >>> dataset = sqlContext.range(0, 100).select((col("id") % 3).a
lias("key"))
 |      >>> sampled = dataset.sampleBy("key", fractions={0: 0.1, 1: 0.
2}, seed=0)
 |      >>> sampled.groupBy("key").count().orderBy("key").show()
 |      +---+-----+
 |      |key|count|
 |      +---+-----+
 |      |  0|    3|
 |      |  1|    8|
 |      +---+-----+
 |
 |      .. versionadded:: 1.5
 |
 |  save(self, path=None, source=None, mode='error', **options)
 |      Saves the contents of the :class:`DataFrame` to a data source.
 |
 |      .. note:: Deprecated in 1.4, use :func:`DataFrameWriter.save` i
nstead.
 |
 |      .. versionadded:: 1.3
 |
 |  saveAsParquetFile(self, path)
 |      Saves the contents as a Parquet file, preserving the schema.
 |
 |      .. note:: Deprecated in 1.4, use :func:`DataFrameWriter.parquet
` instead.
 |
 |  saveAsTable(self, tableName, source=None, mode='error', **options)
 |      Saves the contents of this :class:`DataFrame` to a data source
 as a table.
 |
 |      .. note:: Deprecated in 1.4, use :func:`DataFrameWriter.saveAsT
able` instead.
 |
 |  select(self, *cols)
 |      Projects a set of expressions and returns a new :class:`DataFra
me`.
 |
 |      :param cols: list of column names (string) or expressions (:cla
ss:`Column`).
 |          If one of the column names is '*', that column is expanded
 to include all columns
```

```
 |          in the current DataFrame.
 |
 |      >>> df.select('*').collect()
 |      [Row(age=2, name=u'Alice'), Row(age=5, name=u'Bob')]
 |      >>> df.select('name', 'age').collect()
 |      [Row(name=u'Alice', age=2), Row(name=u'Bob', age=5)]
 |      >>> df.select(df.name, (df.age + 10).alias('age')).collect()
 |      [Row(name=u'Alice', age=12), Row(name=u'Bob', age=15)]
 |
 |      .. versionadded:: 1.3
 |
 |  selectExpr(self, *expr)
 |      Projects a set of SQL expressions and returns a new :class:`Dat
aFrame`.
 |
 |      This is a variant of :func:`select` that accepts SQL expression
s.
 |
 |      >>> df.selectExpr("age * 2", "abs(age)").collect()
 |      [Row((age * 2)=4, 'abs(age)=2), Row((age * 2)=10, 'abs(age)=5)]
 |
 |      .. versionadded:: 1.3
 |
 |  show(self, n=20, truncate=True)
 |      Prints the first ``n`` rows to the console.
 |
 |      :param n: Number of rows to show.
 |      :param truncate: Whether truncate long strings and align cells
 right.
 |
 |      >>> df
 |      DataFrame[age: int, name: string]
 |      >>> df.show()
 |      +---+-----+
 |      |age| name|
 |      +---+-----+
 |      |  2|Alice|
 |      |  5|  Bob|
 |      +---+-----+
 |
 |      .. versionadded:: 1.3
 |
 |  sort(self, *cols, **kwargs)
 |      Returns a new :class:`DataFrame` sorted by the specified column
(s).
 |
 |      :param cols: list of :class:`Column` or column names to sort b
y.
 |      :param ascending: boolean or list of boolean (default True).
 |          Sort ascending vs. descending. Specify list for multiple so
rt orders.
 |          If a list is specified, length of the list must equal lengt
h of the `cols`.
 |
 |      >>> df.sort(df.age.desc()).collect()
 |      [Row(age=5, name=u'Bob'), Row(age=2, name=u'Alice')]
 |      >>> df.sort("age", ascending=False).collect()
```

```
 |      [Row(age=5, name=u'Bob'), Row(age=2, name=u'Alice')]
 |      >>> df.orderBy(df.age.desc()).collect()
 |      [Row(age=5, name=u'Bob'), Row(age=2, name=u'Alice')]
 |      >>> from pyspark.sql.functions import *
 |      >>> df.sort(asc("age")).collect()
 |      [Row(age=2, name=u'Alice'), Row(age=5, name=u'Bob')]
 |      >>> df.orderBy(desc("age"), "name").collect()
 |      [Row(age=5, name=u'Bob'), Row(age=2, name=u'Alice')]
 |      >>> df.orderBy(["age", "name"], ascending=[0, 1]).collect()
 |      [Row(age=5, name=u'Bob'), Row(age=2, name=u'Alice')]
 |
 |      .. versionadded:: 1.3
 |
 |  subtract(self, other)
 |      Return a new :class:`DataFrame` containing rows in this frame
 |      but not in another frame.
 |
 |      This is equivalent to `EXCEPT` in SQL.
 |
 |      .. versionadded:: 1.3
 |
 |  take(self, num)
 |      Returns the first ``num`` rows as a :class:`list` of :class:`Ro
w`.
 |
 |      >>> df.take(2)
 |      [Row(age=2, name=u'Alice'), Row(age=5, name=u'Bob')]
 |
 |      .. versionadded:: 1.3
 |
 |  toJSON(self, use_unicode=True)
 |      Converts a :class:`DataFrame` into a :class:`RDD` of string.
 |
 |      Each row is turned into a JSON document as one element in the r
eturned RDD.
 |
 |      >>> df.toJSON().first()
 |      u'{"age":2,"name":"Alice"}'
 |
 |      .. versionadded:: 1.3
 |
 |  toPandas(self)
 |      Returns the contents of this :class:`DataFrame` as Pandas ``pan
das.DataFrame``.
 |
 |      This is only available if Pandas is installed and available.
 |
 |      >>> df.toPandas()  # doctest: +SKIP
 |         age   name
 |      0    2  Alice
 |      1    5    Bob
 |
 |      .. versionadded:: 1.3
 |
 |  unionAll(self, other)
 |      Return a new :class:`DataFrame` containing union of rows in thi
s
```

```
 |      frame and another frame.
 |      
 |      This is equivalent to `UNION ALL` in SQL.
 |      
 |      .. versionadded:: 1.3
 |  
 |  unpersist(self, blocking=True)
 |      Marks the :class:`DataFrame` as non-persistent, and remove all
 blocks for it from
 |      memory and disk.
 |      
 |      .. versionadded:: 1.3
 |  
 |  where = filter(self, condition)
 |  
 |  withColumn(self, colName, col)
 |      Returns a new :class:`DataFrame` by adding a column or replacin
g the
 |      existing column that has the same name.
 |      
 |      :param colName: string, name of the new column.
 |      :param col: a :class:`Column` expression for the new column.
 |      
 |      >>> df.withColumn('age2', df.age + 2).collect()
 |      [Row(age=2, name=u'Alice', age2=4), Row(age=5, name=u'Bob', age
2=7)]
 |      
 |      .. versionadded:: 1.3
 |  
 |  withColumnRenamed(self, existing, new)
 |      Returns a new :class:`DataFrame` by renaming an existing colum
n.
 |      
 |      :param existing: string, name of the existing column to rename.
 |      :param col: string, new name of the column.
 |      
 |      >>> df.withColumnRenamed('age', 'age2').collect()
 |      [Row(age2=2, name=u'Alice'), Row(age2=5, name=u'Bob')]
 |      
 |      .. versionadded:: 1.3
 |  
 |  ----------------------------------------------------------------------
---
 |  Data descriptors defined here:
 |  
 |  __dict__
 |      dictionary for instance variables (if defined)
 |  
 |  __weakref__
 |      list of weak references to the object (if defined)
 |  
 |  columns
 |      Returns all column names as a list.
 |      
 |      >>> df.columns
 |      ['age', 'name']
 |      
```

```
 |      .. versionadded:: 1.3
 |
 |  dtypes
 |      Returns all column names and their data types as a list.
 |
 |      >>> df.dtypes
 |      [('age', 'int'), ('name', 'string')]
 |
 |      .. versionadded:: 1.3
 |
 |  na
 |      Returns a :class:`DataFrameNaFunctions` for handling missing va
lues.
 |
 |      .. versionadded:: 1.3.1
 |
 |  rdd
 |      Returns the content as an :class:`pyspark.RDD` of :class:`Row`.
 |
 |      .. versionadded:: 1.3
 |
 |  schema
 |      Returns the schema of this :class:`DataFrame` as a :class:`type
s.StructType`.
 |
 |      >>> df.schema
 |      StructType(List(StructField(age,IntegerType,true),StructField(n
ame,StringType,true)))
 |
 |      .. versionadded:: 1.3
 |
 |  stat
 |      Returns a :class:`DataFrameStatFunctions` for statistic functio
ns.
 |
 |      .. versionadded:: 1.4
 |
 |  write
 |      Interface for saving the content of the :class:`DataFrame` out
 into external storage.
 |
 |      :return: :class:`DataFrameWriter`
 |
 |      .. versionadded:: 1.4
```

How many partitions will the DataFrame be split into?

In [24]:
```
dataDF.rdd.getNumPartitions()
```

Out[24]: 128

A note about DataFrames and queries

When you use DataFrames or Spark SQL, you are building up a *query plan*. Each transformation you apply to a DataFrame adds some information to the query plan. When you finally call an action, which triggers execution of your Spark job, several things happen:

1. Spark's Catalyst optimizer analyzes the query plan (called an *unoptimized logical query plan*) and attempts to optimize it. Optimizations include (but aren't limited to) rearranging and combining `filter()` operations for efficiency, converting `Decimal` operations to more efficient long integer operations, and pushing some operations down into the data source (e.g., a `filter()` operation might be translated to a SQL `WHERE` clause, if the data source is a traditional SQL RDBMS). The result of this optimization phase is an *optimized logical plan*.
2. Once Catalyst has an optimized logical plan, it then constructs multiple *physical* plans from it. Specifically, it implements the query in terms of lower level Spark RDD operations.
3. Catalyst chooses which physical plan to use via *cost optimization*. That is, it determines which physical plan is the most efficient (or least expensive), and uses that one.
4. Finally, once the physical RDD execution plan is established, Spark actually executes the job.

You can examine the query plan using the `explain()` function on a DataFrame. By default, `explain()` only shows you the final physical plan; however, if you pass it an argument of `True`, it will show you all phases.

(If you want to take a deeper dive into how Catalyst optimizes DataFrame queries, this blog post, while a little old, is an excellent overview: [Deep Dive into Spark SQL's Catalyst Optimizer (https://databricks.com/blog/2015/04/13/deep-dive-into-spark-sqls-catalyst-optimizer.html)](https://databricks.com/blog/2015/04/13/deep-dive-into-spark-sqls-catalyst-optimizer.html).)

Let's add a couple transformations to our DataFrame and look at the query plan on the resulting transformed DataFrame. Don't be too concerned if it looks like gibberish. As you gain more experience with Apache Spark, you'll begin to be able to use `explain()` to help you understand more about your DataFrame operations.

In [25]:
```
newDF = dataDF.distinct().select('*')
newDF.explain(True)
```

```
== Parsed Logical Plan ==
'Project [*]
 Aggregate [last_name#0,first_name#1,ssn#2,occupation#3,age#4L], [last_
name#0,first_name#1,ssn#2,occupation#3,age#4L]
  LogicalRDD [last_name#0,first_name#1,ssn#2,occupation#3,age#4L], MapP
artitionsRDD[5] at applySchemaToPythonRDD at NativeMethodAccessorImpl.j
ava:-2

== Analyzed Logical Plan ==
last_name: string, first_name: string, ssn: string, occupation: string,
age: bigint
Project [last_name#0,first_name#1,ssn#2,occupation#3,age#4L]
 Aggregate [last_name#0,first_name#1,ssn#2,occupation#3,age#4L], [last_
name#0,first_name#1,ssn#2,occupation#3,age#4L]
  LogicalRDD [last_name#0,first_name#1,ssn#2,occupation#3,age#4L], MapP
artitionsRDD[5] at applySchemaToPythonRDD at NativeMethodAccessorImpl.j
ava:-2

== Optimized Logical Plan ==
Aggregate [last_name#0,first_name#1,ssn#2,occupation#3,age#4L], [last_n
ame#0,first_name#1,ssn#2,occupation#3,age#4L]
 LogicalRDD [last_name#0,first_name#1,ssn#2,occupation#3,age#4L], MapPa
rtitionsRDD[5] at applySchemaToPythonRDD at NativeMethodAccessorImpl.ja
va:-2

== Physical Plan ==
TungstenAggregate(key=[last_name#0,first_name#1,ssn#2,occupation#3,age#
4L], functions=[], output=[last_name#0,first_name#1,ssn#2,occupation#3,
age#4L])
 TungstenExchange hashpartitioning(last_name#0,first_name#1,ssn#2,occup
ation#3,age#4L)
  TungstenAggregate(key=[last_name#0,first_name#1,ssn#2,occupation#3,ag
e#4L], functions=[], output=[last_name#0,first_name#1,ssn#2,occupation#
3,age#4L])
   Scan PhysicalRDD[last_name#0,first_name#1,ssn#2,occupation#3,age#4L]

Code Generation: true
```

(3c): Subtract one from each value using *select*

So far, we've created a distributed DataFrame that is split into many partitions, where each partition is stored on a single machine in our cluster. Let's look at what happens when we do a basic operation on the dataset. Many useful data analysis operations can be specified as "do something to each item in the dataset". These data-parallel operations are convenient because each item in the dataset can be processed individually: the operation on one entry doesn't effect the operations on any of the other entries. Therefore, Spark can parallelize the operation.

One of the most common DataFrame operations is `select()`, and it works more or less like a SQL `SELECT` statement: You can select specific columns from the DataFrame, and you can even use `select()` to create *new* columns with values that are derived from existing column values. We can use `select()` to create a new column that decrements the value of the existing `age` column.

`select()` is a *transformation*. It returns a new DataFrame that captures both the previous DataFrame and the operation to add to the query (`select`, in this case). But it does *not* actually execute anything on the cluster. When transforming DataFrames, we are building up a *query plan*. That query plan will be optimized, implemented (in terms of RDDs), and executed by Spark *only* when we call an action.

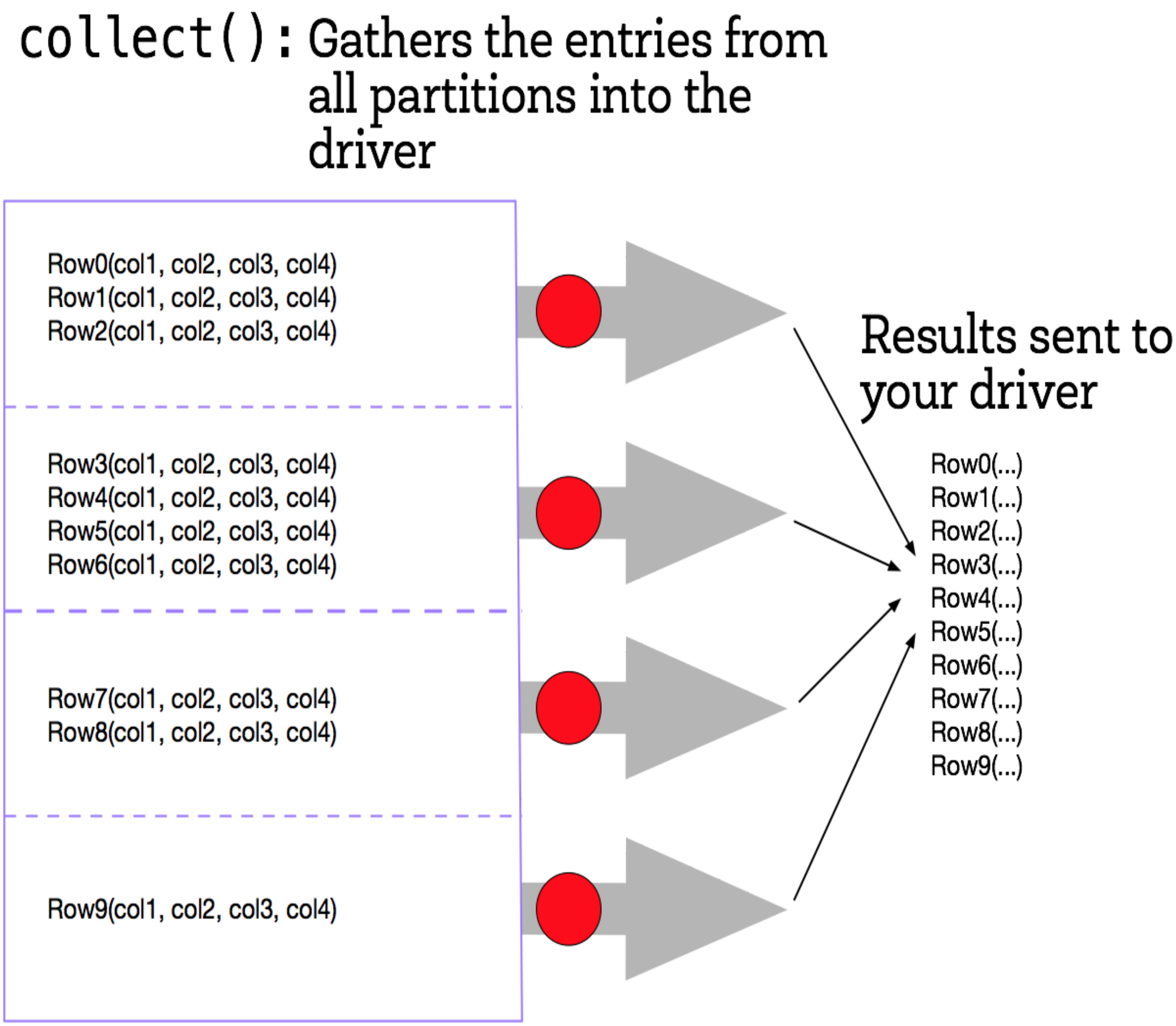
In [26]:
```
# Transform dataDF through a select transformation and rename the newly
created '(age -1)' column to 'age'
# Because select is a transformation and Spark uses lazy evaluation, no
jobs, stages,
# or tasks will be launched when we run this code.
subDF = dataDF.select('last_name', 'first_name', 'ssn', 'occupation',
(dataDF.age - 1).alias('age'))
```

Let's take a look at the query plan.

In [27]:
```
subDF.explain(True)
```

```
== Parsed Logical Plan ==
'Project [unresolvedalias('last_name),unresolvedalias('first_name),unre
solvedalias('ssn),unresolvedalias('occupation),(age#4L - 1) AS age#5]
 LogicalRDD [last_name#0,first_name#1,ssn#2,occupation#3,age#4L], MapPa
rtitionsRDD[5] at applySchemaToPythonRDD at NativeMethodAccessorImpl.ja
va:-2

== Analyzed Logical Plan ==
last_name: string, first_name: string, ssn: string, occupation: string,
age: bigint
Project [last_name#0,first_name#1,ssn#2,occupation#3,(age#4L - cast(1 a
s bigint)) AS age#5L]
 LogicalRDD [last_name#0,first_name#1,ssn#2,occupation#3,age#4L], MapPa
rtitionsRDD[5] at applySchemaToPythonRDD at NativeMethodAccessorImpl.ja
va:-2

== Optimized Logical Plan ==
Project [last_name#0,first_name#1,ssn#2,occupation#3,(age#4L - 1) AS ag
e#5L]
 LogicalRDD [last_name#0,first_name#1,ssn#2,occupation#3,age#4L], MapPa
rtitionsRDD[5] at applySchemaToPythonRDD at NativeMethodAccessorImpl.ja
va:-2

== Physical Plan ==
TungstenProject [last_name#0,first_name#1,ssn#2,occupation#3,(age#4L -
 1) AS age#5L]
 Scan PhysicalRDD[last_name#0,first_name#1,ssn#2,occupation#3,age#4L]

Code Generation: true
```

(3d) Use *collect* to view results



To see a list of elements decremented by one, we need to create a new list on the driver from the the data distributed in the executor nodes. To do this we can call the `collect()` method on our DataFrame. `collect()` is often used after transformations to ensure that we are only returning a *small* amount of data to the driver. This is done because the data returned to the driver must fit into the driver's available memory. If not, the driver will crash.

The `collect()` method is the first action operation that we have encountered. Action operations cause Spark to perform the (lazy) transformation operations that are required to compute the values returned by the action. In our example, this means that tasks will now be launched to perform the `createDataFrame`, `select`, and `collect` operations.

In the diagram, the dataset is broken into four partitions, so four `collect()` tasks are launched. Each task collects the entries in its partition and sends the result to the driver, which creates a list of the values, as shown in the figure below.

Now let's run `collect()` on `subDF`.

In [28]:

```
# Let's collect the data
results = subDF.collect()
print results
```

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