Structural Bioinformatics Training Workshop & Hackathon 2017

Apache Spark Introduction

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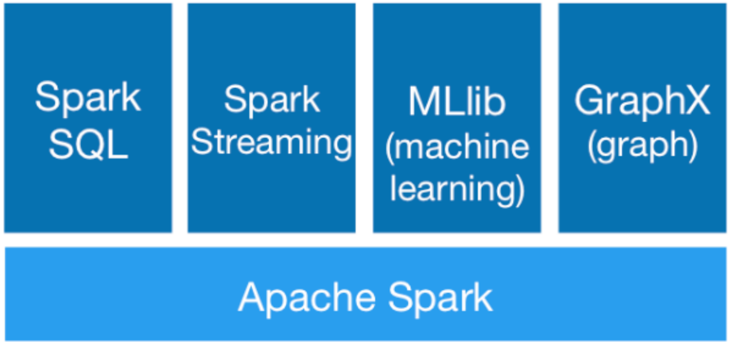
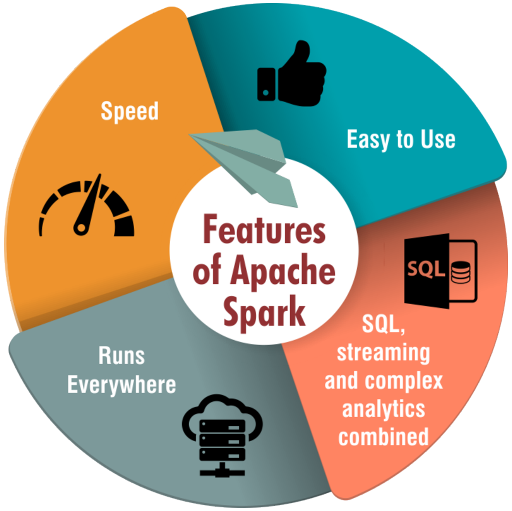
Introduction to Apache Spark

Apache Spark is an open-source software framework that provides a distributed environment designed to store and process big data.

Apache Spark Ecosystem



Core API: Python, Java, R, Scala



Spark offers support for multiple languages and makes it easy to build parallel applications.

Initialize and close Spark

```
import org.apache.spark.SparkConf;
import org.apache.spark.JavaSparkContext;
```

SparkConf object contains information about your application

```
SparkConf conf = new SparkConf()
        .setAppName(”myAppName")
        .setMaster("local[*]")
        .config("spark.driver.maxResultSize", "4g");
```

https://spark.apache.org/docs/latest/configuration.html#available-properties

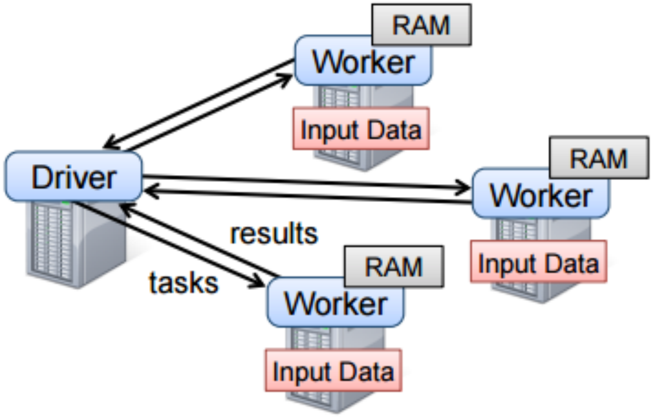
SparkContext is the entry point for interacting with Spark

```
JavaSparkContext sc = new JavaSparkContext(conf);
...
sc.stop();
```

Distributed data structures

Spark revolves around the concept of a *resilient distributed dataset* (RDD):

- core Spark abstraction
- represents partitions across the cluster nodes
- enables parallel processing of datasets
- partitions can be in-memory or on-disk
- partitions can be recomputed on failure



There are two ways to create RDDs:

- parallelizing an existing collection in your driver program
- referencing a dataset in an external storage system

Create JavaRDD

Parallelizing an existing Java collection:

```
List<String> data = Arrays.asList("pandas", "I like pandas");
JavaRDD<String> lines = sc.parallelize(data, 10);
```

Java collection *Number of partitions*

□ *Problem01*

Referencing to a datasets on external storage:

```
JavaRDD<String> lines = sc.textFile("data.txt");
```

□ *Problem02*

Apart from text files, Spark’s Java API also supports several other data formats:

- `.wholeTextFiles` lets you read a directory containing multiple small text files;
- `.sequenceFile[K, V]` for Hadoop Sequence Files;
- other Hadoop input formats.

RDD operations

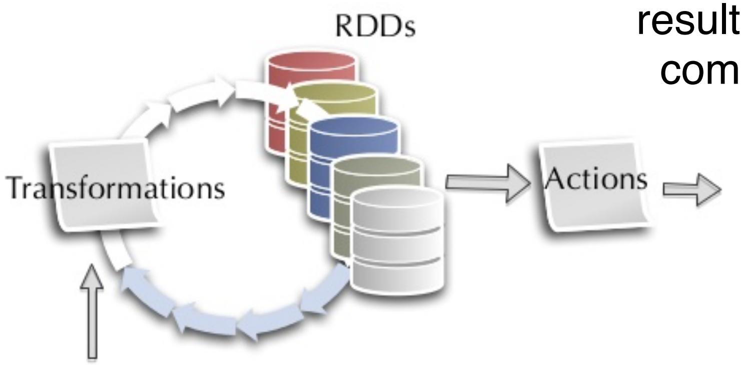
Spark provides a rich set of operators to manipulate RDDs

Transformations

- `map(func)`
- `flatMap(func)`
- `filter(func)`
- `groupByKey()`
- `reduceByKey(func)`
- `mapValues(func)`
- …

Actions

- `take(N)`
- `count()`
- `collect()`
- `reduce(func)`
- `takeOrdered(N)`
- `top(N)`
- …



Actions return final results of RDD computations

Transformations create new RDD from existing RDD

```
JavaRDD<String> data = sc.parallelize(Arrays.asList(”Hello World!", ”Hi"));
JavaRDD<String> twoWords = data.filter(func1);
twoWords.count();
twoWords.collect();
```

```
.cache()
.persist()
```

RDD transformations: filter()

Filter :	filter(f : T ⇒ Bool)	JavaRDD<T> $_{n}$ ⇒ JavaRDD<T> $_{m \leq n}$

Passing anonymous functions:

```
JavaRDD<Integer> rdd2 = rdd1.filter( e -> e % 2 == 0 )
```

□ *Problem03*

Passing functions:

```
JavaRDD<Integer> rdd2 = rdd1.filter(new Function<Integer, Boolean>() {
   @Override
   public Boolean call(Integer e) throws Exception {
      return e % 2 == 0;
   }
});
```

the interfaces available in the *org.apache.spark.api.java.function* package

RDD transformations: map() and flatMap()

Map :	map(f : T ⇒ U)	JavaRDD<T>$_n$ ⇒ JavaRDD<U>$_n$
FlatMap :	flatMap(f : T ⇒ List<U>)	JavaRDD<T>$_n$ ⇒ JavaRDD<U>$_{m \geq n}$

```
JavaRDD<Integer> numbersRDD = context.parallelize(Arrays.asList(1,2,3));

JavaRDD<Integer> squaresRDD = numbersRDD.map( n -> n*n );

JavaRDD<String> stringRDD = numbersRDD.map( n -> String.valueOf(n));

JavaRDD<Integer> multipliedRDD = numbersRDD

                .flatMap( n->Arrays.asList(n,n*2,n*3).iterator());
```

☐ *Problem04*

RDD actions: reduce() and collect()

Spark RDD reduce function reduces the elements of this RDD using the specified commutative and associative binary operator

```
JavaRDD<Integer> rdd = sc.parallelize(Arrays.asList(8,0,5,3,10,6));

long total = rdd.reduce( (n1,n2) -> n1+n2 );
```

Return all the elements of the dataset as an array

```
JavaRDD<Integer> rdd = sc.parallelize(Arrays.asList(8,0,5,3,10,6));

List<Integer> list = rdd.collect();
```

Working with Key/Value Pairs: JavaPairRDD

Key/Value pairs are stored using the *scala.Tuple2* class

Calling a function that returns a key/value pair, for instance, the mapToPair ():

```
List<String> data = Arrays.asList("pandas", "I like pandas");
JavaRDD<String> lines = sc.parallelize(data);
JavaPairRDD<Integer, String> wordsCount = lines
      .mapToPair(line -> new Tuple2(line.split(" ").length, line));
```

❑ *Problem05*

Some methods on *SparkContext* produce pair RDD by default for reading files in certain Hadoop formats

```
sc.sequenceFile(path, Text.class, BytesWritable.class);
```

Working with JavaPairRDD

```
JavaPairRDD<Integer, String> wordsCount;
JavaRDD<Integer> rddKeys = wordsCount.keys();
JavaRDD<String> rddValues = wordsCount.values();
```

Pass each value in the pair RDD through a map function without changing the keys;

```
JavaPairRDD<K,V> rdd1;
JavaPairRDD<K,U> rdd2 = rdd1.mapValues(Function<V, U> f);
```

□ *Problem06, 07*

Pass each value in the pair RDD through a flatMap function without changing the keys

```
JavaPairRDD<K,V> rdd1;
JavaPairRDD<K,U> rdd2 = rdd1.flatMapValues(Function<V,Iterable<U>> f);
```

□ *Problem08*

JavaPairRDD: flatMapToPair()

`PairFlatMapFunction` returns zero or more key-value pair records from each input record

```
JavaPairRDD<K,V> rdd1;                                    Tuple2
JavaPairRDD<K,U> rdd2 = rdd1
        .flatMapToPair(PairFlatMapFunction<T,K,V> f);

                           Iterator<Tuple2<K,V>> call(T t)
```

❑ *Problem09*

`FlatMapFunction` returns a record from each input key-value record

```
JavaPairRDD<K,V> rdd1;
JavaRDD<U> rdd2 = rdd1.flatMap(FlatMapFunction<T,U> f);
```

Transformations on PairRDDs

When called on a dataset of (K, V) pairs, returns a dataset of (K, Iterable<V>) pairs

```
JavaPairRDD<String, String> rdd1;

JavaPairRDD<String, Iterable<String>> rdd2 = rdd1.groupByKey();
```

□ *Problem10*

When called on a dataset of (K, V) pairs, returns a dataset of (K, V) pairs where the values for each key are aggregated using the given reduce function *func: (V,V) => V*

```
JavaPairRDD<String, Integer> rdd1;

JavaPairRDD<String, Integer> rdd2 = rdd1.reduceByKey(func);
```

□ *Problem11*

Actions on PairRDDs

collect()	Return all the elements of the dataset as an array at the driver program. This is usually useful after a filter or other operation that returns a sufficiently small subset of the data.
count()	Return the number of elements in the dataset.
first()	Return the first element of the dataset (similar to take(1)).
take(*n*)	Return an array with the first *n* elements of the dataset.

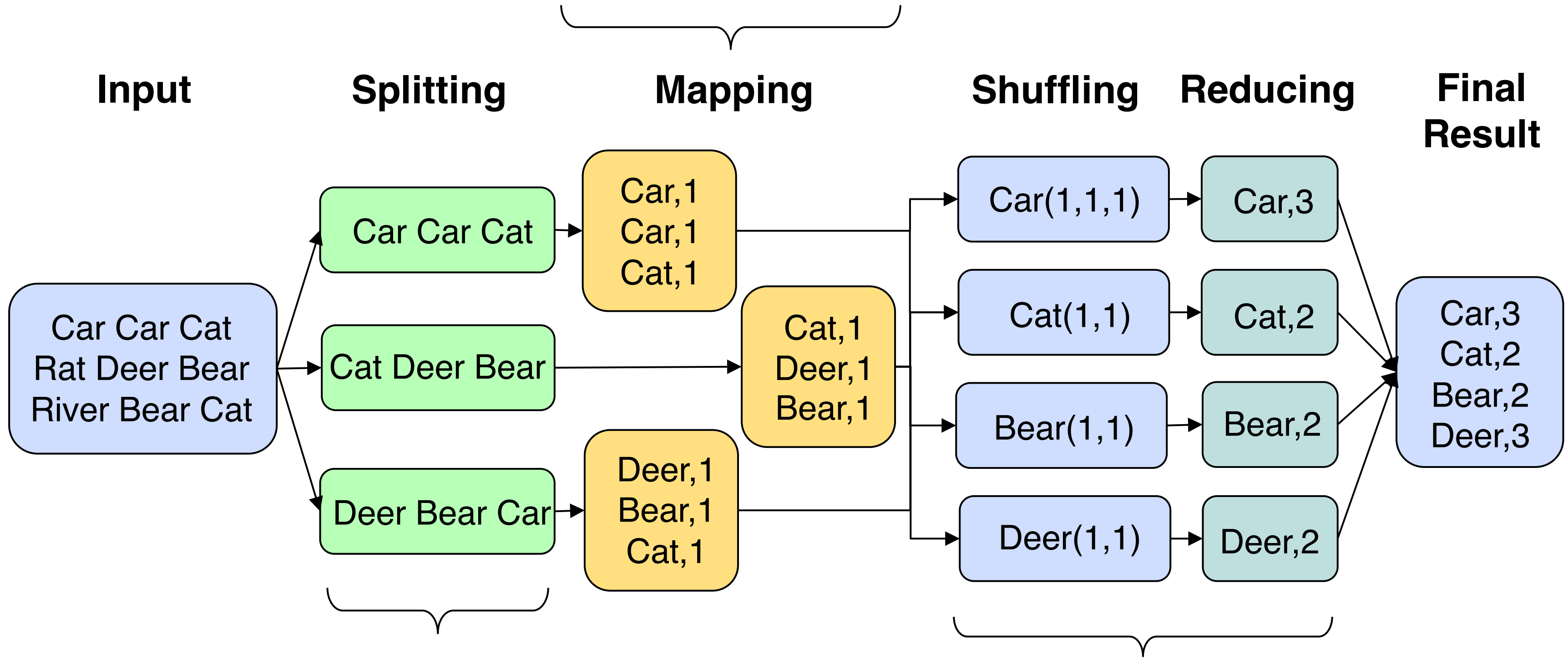
```
JavaPairRDD<String, Integer> pairRdd;

List<Tuple2<String, Integer>> list = pairRdd.collect();
```

saveAsTextFile(*path*)	Write the elements of the dataset as a text file (or set of text files) in a given directory in the local filesystem
saveAsSequenceFile(*path*)	Write the elements of the dataset as a Hadoop SequenceFile in a given path in the local filesystem

Word count with Spark

The overall word count process:

```
JavaPairRDD<String, Integer> pairRdd = rdd.mapToPair();
```



```
JavaRDD<String> rdd = sc
                .parallelize();
```

```
pairRdd.reduceByKey((x, y) -> x + y)
```

Apache Spark Dataset

The Datasets API provides the benefits of RDDs (strong typing, ability to use lambda functions) with the benefits of Spark SQL’s optimized execution engine

```
SparkSession ss = SparkSession.builder()
      .master("local[*]").appName("app")
      .config("spark.driver.maxResultSize", "4g")
      .config("spark.executor.memory", "4g")
      .getOrCreate();
```

```
Dataset<Row> data = sparkSession.read().scv(...);
```

❑ *Problem12*

```
List<Person> data;
Dataset<Row> dataset = ss.createDataset(data, Person.class);
```

❑ *Problem13*

Querying Dataset: SQL API

SQL statements can be run by using the SQL methods provided by spark

```
Dataset<Row> peopleDF = spark.createDataFrame(peopleRDD, Person.class);

peopleDF.createOrReplaceTempView("people");
Dataset<Row> teenagersDF = spark
        .sql("SELECT name FROM people WHERE age BETWEEN 13 AND 19");
```

```
Dataset<Row> peopleDF;
Dataset<Row> gilrsDF = peopleDF.select(col(“gender”).equalsTo(“F”))
                        .filter(col(“age”).geq(13)
                                .and(col(“age”).geq(19)));
```

❑ *Problem14*

Thanks!