

Structural Bioinformatics Training Workshop & Hackathon 2017

Apache Spark Introduction

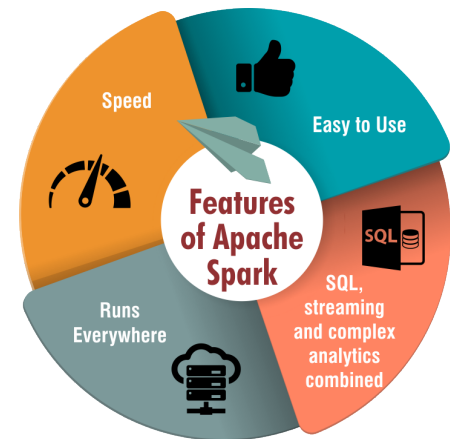
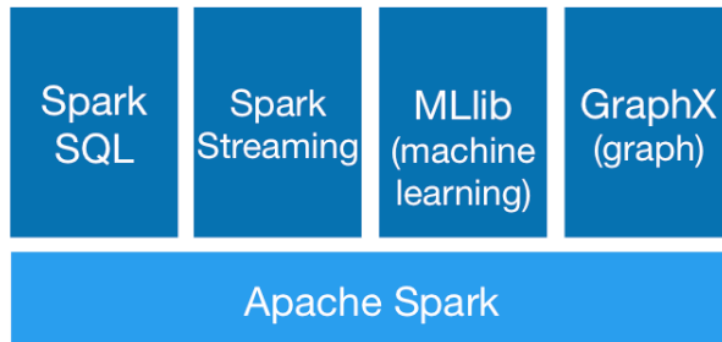
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Introduction to Apache Spark

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, SQL

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>

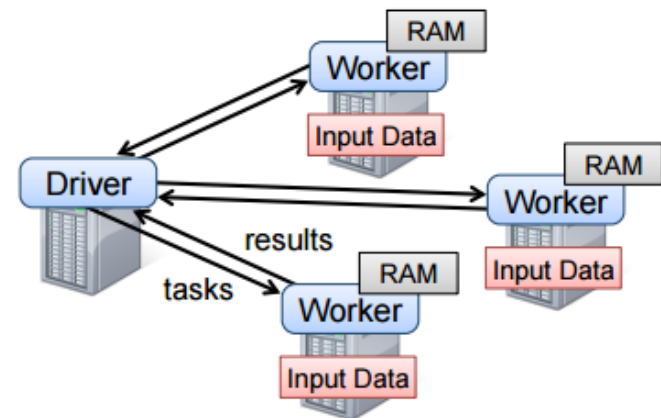
SparkContext is the entry point for interacting with Spark

```
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*

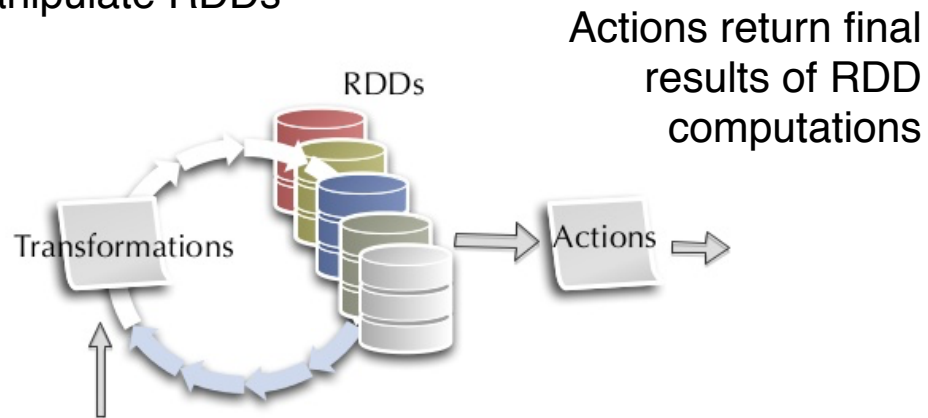
Apart from text files, Spark's Java API also supports several other data formats:

- `.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	Actions
<code>map(func)</code>	<code>take(N)</code>
<code>flatMap(func)</code>	<code>count()</code>
<code>filter(func)</code>	<code>collect()</code>
<code>groupByKey()</code>	<code>reduce(func)</code>
<code>reduceByKey(func)</code>	<code>takeOrdered(N)</code>
<code>mapValues(func)</code>	<code>top(N)</code>
...	...



```
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 \Rightarrow Bool)`

`JavaRDD<T>n \Rightarrow 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 :	$\text{map}(f : T \Rightarrow U)$	$\text{JavaRDD}\langle T \rangle_n \Rightarrow \text{JavaRDD}\langle U \rangle_n$
FlatMap :	$\text{flatMap}(f : T \Rightarrow \text{List}\langle U \rangle)$	$\text{JavaRDD}\langle T \rangle_n \Rightarrow \text{JavaRDD}\langle U \rangle_{m \geq n}$

```
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;  
JavaPairRDD<K,U> rdd2 = rdd1  
    .flatMapToPair(PairFlatMapFunction<T,K,V> f);  
                    ↑  
                    Tuple2  
                    ↑  
                    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*: $(V, V) \Rightarrow V$

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

❑ *Problem11*

Actions on PairRDDs

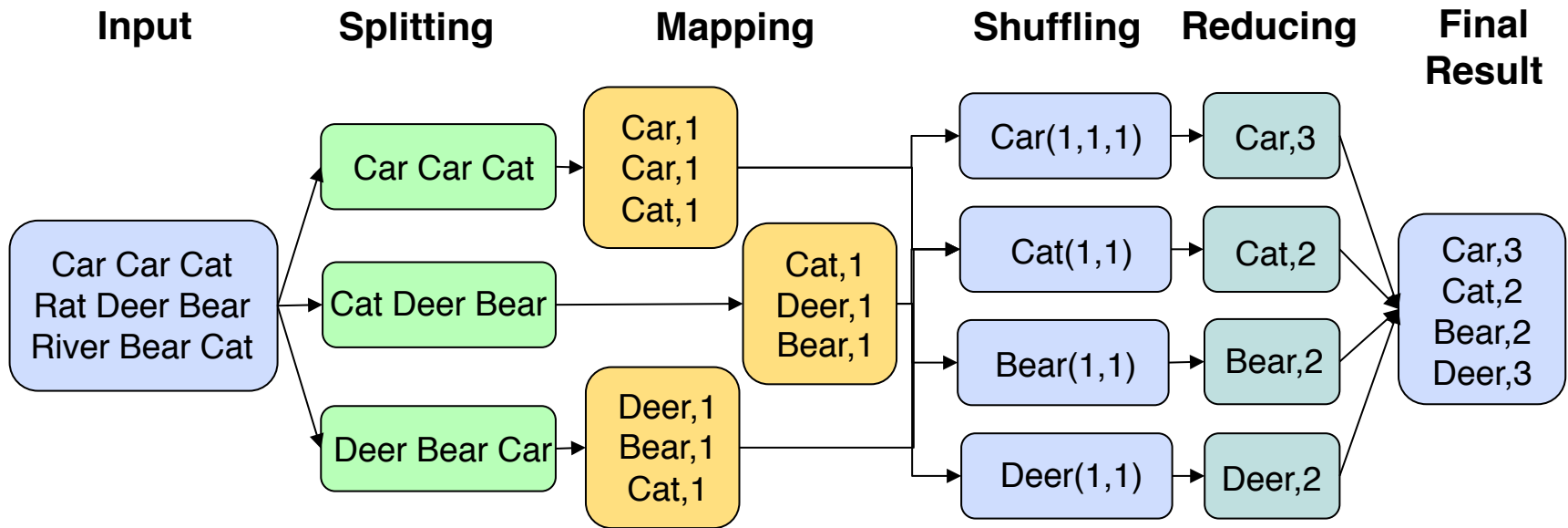
collect()	Return all the elements of the dataset as an array at the driver program. This is usually useful after a filter or other operation that returns a sufficiently small subset of the data.
count()	Return the number of elements in the dataset.
first()	Return the first element of the dataset (similar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



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").equalTo("F"))
    .filter(col("age").geq(13)
        .and(col("age").geq(19)));
```

□ *Problem14*

Thanks!