Big data: architectures and data analytics

Spark MLlib

Textual data classification

Textual data classification

- The following slides show how to
  - Create a classification model based on the logistic regression algorithm for **textual documents**
  - Apply the model to new textual documents
- The input training dataset represents a textual document collection
  - Each line contains one document and its class
    - The class label
    - A list of words (the text of the document)

Textual data classification

- Consider the following example file

  1,The Spark system is based on scala

  1,Spark is a new distributed system

  0,Turin is a beautiful city

  0,Turin is in the north of Italy
- It contains four textual documents
- Each line contains two attributes
  - The class label (first attribute)
  - The text of the document (second attribute)

Textual data classification

- Input data before pre-processing

Label	Text
1	The Spark system is based on scala
1	Spark is a new distributed system
0	Turin is a beautiful city
0	Turin is in the north of Italy

Textual data classification

- A set of preprocessing steps must be applied on the textual attribute before generating a classification model

Textual data classification

1. Since Spark ML algorithms work only on "Tables", the textual part of the input data must be translated in a set of attributes in order to represent the data as a table
   - Usually a table with an attribute for each word is generated

Textual data classification

2. Many words are useless (e.g., conjunctions)
   - Stopwords are usually removed

Textual data classification

- The words appearing in almost all documents are not characterizing the data
  - Hence, they are not very important for the classification problem
- The words appearing in few documents allow distinguish the content of those documents (and hence the class label) with respect to the others
  - Hence, they are very important for the classification problem

Textual data classification

3. Traditionally a weight, based on the TF-IDF measure, is used to assign a difference importance to the words based on their frequency in the collection

Textual data classification

- Input data after the pre-processing transformations (tokenization, stopword removal, TF-IDF computation)

Label	Spark	system	scala	.....
1	0.5	0.3	0.75	..
1	0.5	0.3	0	…
0	0	0	0	…
0	0	0	0	…

Textual data classification

- The Dataset<Row> associated with input data after the pre-processing transformations must contain, as usual, the columns
  - label
    - Class label value
  - features
    - The pre-processed version of the input text
  - There are also some other intermediate columns, related to applied transformations, but they are not considered by the classification algorithm

Textual data classification

- The Dataset<Row> associated with input data after the pre-processing transformations must contain, as usual, the columns

label	features	text	.....	.....
1	[0.5, 0.3, 0.75, ..]	The Spark system is based on scala	..	..
1	[0.5, 0.3, 0, ..]	Spark is a new distributed system	...	...
0	[0, 0, 0, ..]	Turin is a beautiful city	...	...
0	[0, 0, 0, ..]	Turin is in the north of Italy	...	...

Textual data classification

- The Dataset<Row> associated with input data after the pre-processing transformations must contain, as usual, the columns

label	features	text	.....	.....
1	[0.5, 0.3, 0.75, ..]	The Spark system is based on scala	..	..
1	[0.5, 0.3, 0, ..]	Spark is a new distributed system	...	...
0	[0, 0, 0, ..]	Turin is a beautiful city	...	...
0	[0, 0, 0, ..]	Turin is in the north of Italy	...	...

Only "label" and "features" are considered by the classification algorithm

Textual data classification: example

```
package it.polito.bigdata.spark.sparkmllib;

import java.io.Serializable;

public class LabeledDocument implements Serializable {
	private double label;
	private String text;

	public LabeledDocument(double label, String text) {
	  this.text = text;
	  this.label = label;
	}
```

Textual data classification: example

```
    public String getText() { return this.text; }
    public void setText(String text) { this.text = text; }

    public double getLabel() { return this.label; }
    public void setLabel(double label) { this.label = label; }
  }
);
```

Textual data classification: example

```
package it.polito.bigdata.spark.sparkmllib;

import org.apache.spark.api.java.*;
import org.apache.spark.sql.Dataset;
import org.apache.spark.sql.Row;
import org.apache.spark.sql.SparkSession;
import org.apache.spark.ml.Pipeline;
import org.apache.spark.ml.PipelineModel;
import org.apache.spark.ml.PipelineStage;
import org.apache.spark.ml.classification.LogisticRegression;
import org.apache.spark.ml.feature.Tokenizer;
import org.apache.spark.ml.feature.HashingTF;
import org.apache.spark.ml.feature.IDF;
import org.apache.spark.ml.feature.StopWordsRemover;
```

Textual data classification: example

```
public static void main(String[] args) {
        String inputFileTraining;  String inputFileTest; String outputPath;

        inputFileTraining=args[0];
        inputFileTest=args[1];
        outputPath=args[2];

        // Create a Spark Session object and set the name of the application
        // We use some Spark SQL transformation in this program
        SparkSession ss = SparkSession.builder()
                        .appName("MLlib - logistic regression").getOrCreate();

        // Create a Java Spark Context from the Spark Session
        // When a Spark Session has already been defined this method
        // is used to create the Java Spark Context
        JavaSparkContext sc = new JavaSparkContext(ss.sparkContext());
```

Textual data classification: example

```
// ************************
//Training step
// ************************

// Read training data from a textual file
// Each lines has the format: class-label,list of words
// E.g., 1,hadoop mapreduce
JavaRDD<String> trainingData=sc.textFile(inputFileTraining);
```

Textual data classification: example

```
// Map each element (each line of the input file) to a LabeledDocument
// LabeledDocument is a class defined in this application. Each instance
// of LabeledDocument is characterized by two attributes:
// - private double label
//  - private String text
// LabeledDocument represents a "document" and the related class label.
JavaRDD<LabeledDocument> trainingRDD=trainingData.map(record -> {
                        String[] fields = record.split(",");

                        // fields[0] contains the class label
                        double classLabel = Double.parseDouble(fields[0]);

                        //The content of the document is after the comma
                        String text = fields[1];
                        // Return a new LabeledDocument
                        return new LabeledDocument(classLabel, text);
                });
```

Textual data classification: example

```
// Prepare training data.
// We use LabeledDocument, which is a JavaBean.
// We use Spark SQL to convert RDDs of JavaBeans
// into Dataset<Row>. The columns of the Dataset are label
// and features
Dataset<Row> training = ss
            .createDataFrame(trainingRDD, LabeledDocument.class).cache();
```

Textual data classification: example

```
// Configure an ML pipeline, which consists of five stages:
// tokenizer -> split sentences in set of words
// remover -> remove stopwords
// hashingTF -> map set of words to a fixed-length feature vectors  (each
// word becomes a feature and the value of the feature is the frequency of
//  the word in the sentence)
// idf -> compute the idf component of the TF-IDF measure
// lr -> logistic regression classification algorithm

//The Tokenizer splits each sentence in a set of words.
// It analyzes the content of column "text" and adds the
// new column "words" in the returned DataFrame
Tokenizer tokenizer = new Tokenizer()
                .setInputCol("text")
                .setOutputCol("words");
```

Textual data classification: example

```
// Remove stopwords.
// the StopWordsRemover component returns a new DataFrame with
// new column called "filteredWords". "filteredWords" is generated
// by removing the stopwords from the content of column "words"
StopWordsRemover remover = new StopWordsRemover()
                .setInputCol("words")
                .setOutputCol("filteredWords");
```

Textual data classification: example

```
// Map words to a features
// Each word in filteredWords must become a feature in a Vector object
//The HashingTF Transformer performs this operation.
//This operations is based on a hash function and can potentially
// map two different words to the same "feature". The number of conflicts
// in influenced by the value of the numFeatures parameter.
//The "feature" version of the words is stored in Column "rawFeatures".
// Each feature, for a document, contains the number of occurrences
// of that feature in the document (TF component of the TF-IDF measure)
HashingTF hashingTF = new HashingTF()
                .setNumFeatures(1000)
                .setInputCol("filteredWords")
                .setOutputCol("rawFeatures");
```

Textual data classification: example

```
// Apply the IDF transformation.
// Update the weight associated with each feature by considering also the
// inverse document frequency component. The returned new column
// is called "features", that is the standard name for the column that
// contains the  predictive features used to create a classification model
IDF idf = new IDF()
            .setInputCol("rawFeatures")
            .setOutputCol("features");
```

Textual data classification: example

```
// Create a classification model based on the logistic regression algorithm
// We can set the values of the parameters of the
// Logistic Regression algorithm using the setter methods.
LogisticRegression lr = new LogisticRegression()
                .setMaxIter(10)
                .setRegParam(0.01);

// Define the pipeline that is used to create the logistic regression
// model on the training data.
// In this case the pipeline is composed of five steps
// - text tokenizer
// - stopword removal
// - TF-IDF computation (performed in two steps)
// - Logistic regression model generation
Pipeline pipeline = new Pipeline()
  .setStages(new PipelineStage[] {tokenizer, remover, hashingTF, idf, lr});
```

Textual data classification: example

```
// Execute the pipeline on the training data to build the
// classification model
PipelineModel model = pipeline.fit(training);

// Now, the classification model can be used to predict the class label
// of new unlabeled data
```

Textual data classification: example

```
// ***************************
// Prediction  step
// ***************************

// Read unlabeled data
// For the unlabeled data only the predictive attributes are available
// The class label is not available and must be predicted by applying
// the classification model inferred during the previous phase
JavaRDD<String> unlabeledData=sc.textFile(inputFileTest);
```

Textual data classification: example

```
// Map each unlabeled input document of the input file to a
LabeledDocument JavaRDD<LabeledDocument> unlabeledRDD=
unlabeledData.map(record -> {
        String[] fields = record.split(",");
        //The content of the document is after the comma
        String text = fields[1];

        //The class label in unknown.
        //To create a LabeledDocument a class label value must be
        // specified also for the  unlabeled data. I set it to -1 (an invalid
        // value).
        double classLabel = -1;

        // Return a new LabeledDocument
        return new LabeledDocument(classLabel, text);
});
```

Textual data classification: example

```
// Create the DataFrame based on the new unlabeled data
Dataset<Row> unlabeled =
            ss.createDataFrame(unlabeledRDD, LabeledDocument.class);

// Make predictions on unlabeled documents by using the
//Transformer.transform() method.
//The transform will only use the 'features' columns
//The returned DataFrame has the following schema (attributes)
// - features: vector (values of the attributes)
// - label: double (value of the class label)
// - rawPrediction: vector (nullable = true)
// - probability: vector (The i-th cell contains the probability that the
//              current record belongs to the i-th class
// - prediction: double (the predicted class label)

Dataset<Row> predictions = model.transform(unlabeled);
```

Textual data classification: example

```
        // Select only the text and
        // the predicted class for each record/document
        Dataset<Row> predictionsDF=predictions.select("text", "prediction");

        // Save the result in an HDFS file
        JavaRDD<Row> predictionsRDD = predictionsDF.javaRDD();
        predictionsRDD.saveAsTextFile(outputPath);

        // Close the Spark Context object
        sc.close();
    }
}
```