UNIVERSITÀ DI PISA

Master Degree in Artificial Intelligence and Data Engineering

Cloud Computing

Hadoop and Spark PageRank

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Chapter 1

Hadoop Implementation

1.1 Parsing Stage

Algorithm 1 Graph Building Mapper

1: **procedure** Map(Key k, Page p)
2:     $titlePage \leftarrow getTitle(p)$
3:     $outLinks \leftarrow getOutLinks(p)$
4:     **if** outLinks == 0 **then**
5:         EMIT(title, "sinknode")
6:     **else**
7:         **for all** link **in** outLinks **do**
8:             EMIT(title, link)

Algorithm 2 Graph Building Reducer

1: **procedure** Reduce(Title t, Links $[l_1, l_2, \dots]$)
2:     $listOutlinks \leftarrow null$
3:     **for all** l **in** Links **do**
4:         $listOutlinks$.add(l)
5:     EMIT(t, listOutlinks)

We processed every row of the input file *wiki-micro.txt* in order to obtain the following structure:

titlePage $>>$ PageRank $\rightarrow outlink1 \rightarrow outlink2 \rightarrow ... \rightarrow outlinkN$.

In case there are no outlinks, then we have a *sink node*. We decided to add a fake outlink called **"sinknode"** in order to recognise this special nodes in the PageRank Stage.

For the number of **total nodes** we decided to calculate it as the number of rows processed by the mapper in this stage. Because of that the initial pagerank can only be calculated in the first PageRank Stage.

1.2 Page Rank Stage

Algorithm 3 Page Rank Mapper

1: **procedure** SETUP
2: $\quad N \leftarrow totalNumberNodes$
3: $\quad H \leftarrow$ new AssociativeArray

4: **procedure** MAP(Key k, Node n)
5: $\quad$ **if** n.outLinks.size == 0 **then**
6: $\quad\quad$ return
7: $\quad$ **if** n.pageRank == 0 **then**
8: $\quad\quad n.pageRank \leftarrow \frac{1}{N}$
9: $\quad$ EMIT (n.titlePage, {n.pageRank, n.outLinks}) $\qquad\qquad$ ▷ Pass Graph Structure
10: $\quad$ **if** n.outLinks(0) == "sinknode" **then**
11: $\quad\quad$ return
12: $\quad fatherContribution \leftarrow \frac{n.pageRank}{n.outlink.size}$
13: $\quad$ **for all** outLink **in** n.outLink **do**
14: $\quad\quad H\{outLink\}.add(fatherContribution)$

15: **procedure** CLEAN UP
16: $\quad$ **for all** listNode ln **in** H **do**
17: $\quad\quad$ **if** ln.size == 1 **then** then
18: $\quad\quad\quad$ EMIT (titlePage,ln)
19: $\quad\quad$ **else**
20: $\quad\quad\quad sumPR \leftarrow 0$
21: $\quad\quad\quad$ **for all** node **in** ln **do**
22: $\quad\quad\quad\quad sumPR \leftarrow sumPR + node.pageRank$
23: $\quad\quad$ EMIT (titlePage, sumPR)

Algorithm 4 Reducer PageRank

1: **procedure** SETUP
2: $\quad N \leftarrow totalNumberNodes$
3: $\quad alpha \leftarrow getAlpha$

4: **procedure** REDUCE(Title t, Nodes $[n_1, n_2, \dots]$)
5: $\quad sumPR \leftarrow 0$
6: $\quad sendNode \leftarrow null$
7: $\quad$ **for all** node **in** Nodes **do**
8: $\quad\quad$ **if** node.outLinks.size > 0 **then**
9: $\quad\quad\quad$ sendNode = node
10: $\quad\quad$ **else**
11: $\quad\quad\quad sumPR \leftarrow sumPR + node.pageRank$
12: $\quad$ sendNode.pageRank $\leftarrow \frac{alpha}{N}$ + (1-alpha) * sumPR
13: $\quad$ EMIT (t, sendNode)

Differently for the standard PageRank algorithm we adopted some differences. First of all we implemented a custom **NodeWritable** class that implements *Writable*, we use this class to send values as [**PageRank, List<outlinks>**] between mappers and reducers.

In order to reduce the amount of data that have to be transmitted we decided to implement an *inMapper Combiner* in the *clean up* method, in the combiner we calculate the partial pagerank as the sum of all the contribution that appears in the same node.

Moreover we handled *SinkNodes* and *DanglingNode* in a special manner. For the SinkNodes we only emit the title page in order to maintain the graph structure, for the DanglingNode we decided to ignore them because their pagerank will be calculated automatically, since we want them in the final output it is not possible to completely omit them.

1.3 Sorting Stage

Algorithm 5 Sort Mapper

1: **procedure** MAP(Key k, Node n)
2:     EMIT (n.pageRank, n.title)

Algorithm 6 Sort Reducer

1: **procedure** REDUCE(PageRank pr, Titles $[t_1, t_2, \ldots]$)
2:     **for all** all title **in** Titles **do**
3:         EMIT (title, pr)

In this stage we decided to implement a custom **DoubleComparator** class with a redefined *Compare* method that was previously defined in the **DoubleWritable** class. In the mapper we swapped keys with values in order to have the pagerank as a key, in this way with our redefined method we have the ordered output thanks to the *shuffle and sort* mechanism between mapper and reducer.

1.4 Performance

Normally we decided to run our application with 3 reducers in the ranking stage since this is the most computational expensive part. In order to collect some data we changed the number of reducers we used, we tried with a single reducer and then with 6 reducers, we collected the following data.

Number of reducers	Time
1 reducer	115955 ms
3 reducers	119975 ms
6 reducers	128449 ms

As we can see the process time increases with the number or reducers, this strange behaviour may be caused by the small size of the input file. In particular, the increase in execution time is due to the small size of the output from the mapper function, this

brings a significant overhead in IO operations in order to split the output and to assign the chunks to the different reducers.

Thanks to the *inMapper combiner* in the PageRank Stage we managed to reduce the key-value pairs that have to be transmitted from the map to the reduce function. The initial pairs number was **47220**, with the inMapper combiner the total number is **36712**. This consist in a 23% traffic reduction. Implementing the combiner in the PageRank Stage, that is iterated several times, we obtained this traffic reduction for each iteration.

Chapter 2

Spark Implementation

2.1 RDD Persistance

We decided to store using the *cache()* function only two RDDs:

- **input_data**: this RDD is obtained after the *textFile()* function since we use this RDD to count the total node and to compute the total *graph structure*.

- **rows**: this RDD contains the graph structure, we use this RDD multiple times.

2.2 Use of MapValues

This function operates only on the values and not on the entire record, this results in a performace boost. We use this function to set the initial page rank and to calculate the page rank with the total formula, in both cases we do not need to access the key but only the values.
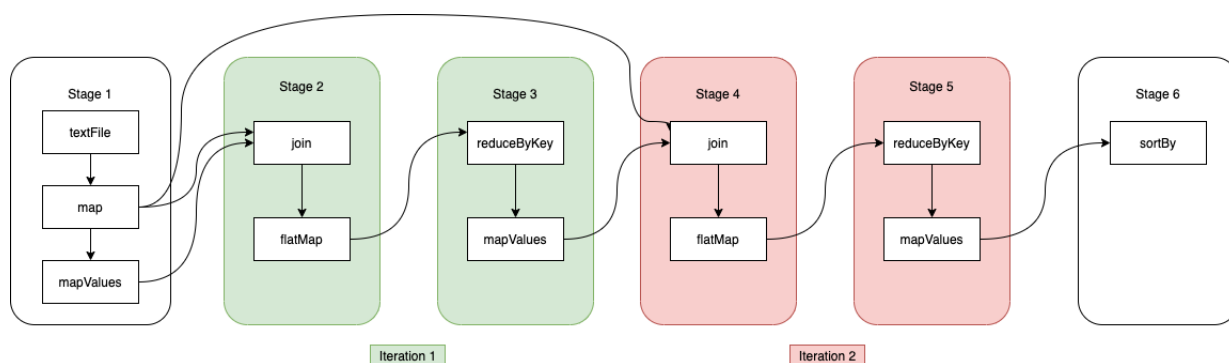
2.3 DAG

Figure 2.1: Spark DAG