CS 549—Summer 2020
Distributed Systems and Cloud Computing
Assignment Four—Page Rank in Hadoop

Implement the PageRank algorithm to find the most popular pages in a set of Web pages. You will use your implementation of PageRank to find the 'most popular' pages in a dump of Wikipedia pages that you are provided with.

Input format: We will assume that the link graph is initially available as a list of vertices and their adjacency lists (a list of "friend" vertices for each vertex). Each entry is a line in a file of the form:

```
node-id: to-node1 to-node2 …
```

In addition, for output purposes, there is separately information about page names for each node, of the form:

```
node-id: page-name
```

Output format: The goal is to produce a file that contains the page rank of each Wikipedia page. There should be one line for each page, and each line should contain the Wikipedia page name (**not** the vertex identifier) and the page rank. The file should be *sorted by rank in reverse order*.

As described in the lectures, PageRank is an iterative algorithm, so you will implement this as an iterative MapReduce. Thus, the output of round k will be used as the input of round k+1. In addition, we will need three additional types of jobs: One for converting the input data into our intermediate format, one for computing how much the rank values have changed from one round to the next (actually made up of two MapReduce jobs), and one for converting the intermediate format into the output format.

The intermediate format for iterative PageRank computations should include the node identifier, page rank, and the adjacency list for that node. Remember that the adjacency list should be propagated through each iteration, having been read from the initial data. You will want to initialize the intermediate data with page ranks of 1 for each page. Note also that Web page names do not appear until the output of the final result; you will need to modify the code to provide this. Use the node identifiers (long integers) to identify nodes during PageRank computations.

You are provided with a driver that will read the command-line arguments and, depending on the first argument, implement the following four functions (you will need to finish the definitions of the mapper/reducer pairs for each):

- `init` *`inputDir outputDir #reducers`*: This job read the file(s) in the input directory, convert thems into your intermediate format, and outputs

the data to the output directory, using the specified number of reducers.

- `iter` *`inputDir outputDir #reducers`*: This job performs a single round of PageRank by reading data in your intermediate format from the input directory, and writing data in your intermediate format to the output directory, using the specified number of reducers.
- `diff` *`inputDir`*$_1$ *`inputDir`*$_2$ *`outputDir #reducers`*: This job reads data in your intermediate format from *both* input directories and outputs a single line that contains the maximum difference between any pair of rank values for the same vertex. You must use absolute values for the differences, i.e., the change from 0.98 to 0.97 is 0.01. While diff runs as a single task, it is implemented using two different MapReduce jobs run successively.
- `finish` *`inputDir outputDir #reducers`*: This job reads data in your intermediate format from the input directory, converts the data to the output format, and outputs it to the output directory, using the specified number of reducers.

Additionally, the driver provides a composite function that needs to be submitted only once and runs the entire PageRank algorithm from beginning to end, i.e., until convergence has occurred.

- `composite` *`inputDir outputDir intermDir`*$_1$ *`intermDir`*$_2$ *`diffDir #reducers`*: This function runs the init task, then it alternates between running the iter and diff tasks until convergence has occurred **(diff <=30 in the case of the test data)**, at which point it runs the finish task and places the output into <outputDir>. Note, running the diff task after every iteration could add considerable time to your job, so this function runs the diff task after every two or three iterations to save computation time.

Each job must delete the output directory if it already exists, and *it must also output your name to `System.out` every time it is invoked*. The main class of your job is `edu.stevens.cs549.hadoop.pagerank.PageRankDriver`. You should document your code sufficiently to enable the grader to understand how you are processing inputs and outputs in mappers and reducers.

You should start with the Eclipse project that is provided, that gives you some code to get you started. This is a Maven project, so be careful to import it as such into your Eclipse workspace. The pom file already imports the requisite Hadoop libraries from global Maven repositories. You should still install Hadoop on your local machine, since you will need its libraries in your classpath when testing your app.

A good way to make sure that your implementation is correct is to test it in pseudo-distributed mode, using the Hadoop installation locally (perhaps in a Linux VM) and the example graph from below. You should only test the composite task after you are sure that the other tasks work properly.

Most of the code is already provided to you. You need to customize the driver to display your name and userid when a job runs, and fill in the missing details in the mappers and reducers. There are comments in the code explaining what the missing code should do, so this is largely an exercise in understanding the Hadoop API, and the implementation of PageRank using Hadoop.

The code you are provided with just outputs the vertex identifiers (with their page ranks). For a full grade, you should output Wikipedia page names at the end. There are two ways to do this. One way is to store the mapping of node identifiers to page names as one or more files in Hadoop's cache, and read this into the mapper or reducer that provides the final output. In your driver, add the mapping file(s) to the cache:

```
job.addCacheFile(…URI in HDFS…);
```

In your mapper/reducer, read this file(s) into memory by overriding the `setup` method:

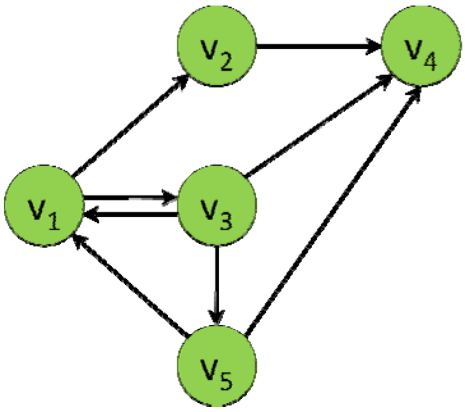
```
public void setup(Context context) {
   super.setup(context);
   URI[] files = context.getCacheFiles();
   Path path = new Path(files[0]);
   …
}
```

A more scalable way to do this is to perform an equipartitioned join of the output page ranks and the page names, where the page name table includes node identifiers as keys.

In this assignment, you should run your Hadoop program for the Wikipedia data set on Amazon Elastic Map-Reduce (EMR). Since EMR does not support the Hadoop cache, you will have to do this using an equipartitioned join.

You should test your PageRank implementation on two sets of data.

First, get it to work on the following example graph. It is sufficient to demonstrate your implementation working locally with Hadoop (perhaps using a VM on which you have installed Hadoop):



Second, use PageRank to find the fifty highest-ranked nodes in Wikipedia, based on information about page links that is provided to you. This data is considerably cleaned up from the dumps provided by Wikipedia, removing dead links and links outside Wikipedia or to images or remarks. It has already been split into multiple files and has been imported into Amazon S3:

http://s3.amazonaws.com/cs549-stevens/links-simple-sorted.tgz

In addition, there is a collection of files that map node identifiers to page names:

http://s3.amazonaws.com/cs549-stevens/page-names.tgz

Submitting

Once you have your code working, please follow these instructions for submitting your assignment:

- Export your Eclipse project to the file system.
- Create a zip archive file, named after you, containing a directory with your name. E.g. if your name is Humphrey Bogart, then name the directory Humphrey_Bogart.
- In that directory you should provide the zip archive that contains your sources, your Hadoop app jar file, PageRank.jar, and the test data that you used locally.
- Also include in the directory a report of your submission. This report should be in PDF format. **Do not provide a Word document.**

The content of the report is very important. A missing or sloppy report will hurt your final grade, even if you get everything working. In this report, describe how you completed the code for M/R, with a particular focus on the representations that you used for inputs to and outputs from the map and reduce steps. You should also describe how you tested the code. For testing with the Wikipedia data, try testing with a different number of reducers (say, five versus twenty), and comment on the

difference in the results. Again, it is very important for your grade that you do adequate testing.

You should also provide a video of your local testing, *on the small test graph*. Remember that your name should be displayed on each iteration of the job.

You should also provide a video showing your setting up and starting a run on the Wikipedia data. You should test your app on the Wikipedia data using Amazon AWS Elastic Map Reduce (EMR). Make sure your name is visible in the video! There is obviously no point in showing the entire run in EMR, since it will take some time, the video should just show you starting the program running.

Remember the format of the submission: A zip archive file, named after you, with a directory named after you. In this directory, provide a zip archive of your source files and resources, a jar file of your submission, a report for your submission, and videos. Do **not** upload the Wikipedia data as part of your submission.