

CSL7110: Big Data Frameworks

Assignment Report

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GitHub Repository

The complete source code for this assignment is available at: https://github.com/Ravi110296/CSL7110_Assignment/blob/main

1 Apache Hadoop and MapReduce

1.1 Question 1: Running WordCount Example

The WordCount example provided by Apache Hadoop was executed successfully to verify the correct setup of the Hadoop environment.

Snapshots

```
root@LAPTOP-CPCUQN0J:~# hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.3.6.jar wordcount /user/root/input /user/root/output
2026-02-06 19:59:28,329 INFO impl.MetricsConfig: Loaded properties from hadoop-metrics2.properties
2026-02-06 19:59:28,446 INFO impl.MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
2026-02-06 19:59:28,446 INFO impl.MetricsSystemImpl: JobTracker metrics system started
2026-02-06 19:59:28,711 INFO input.FileInputFormat: Total input files to process : 1
2026-02-06 19:59:28,738 INFO mapreduce.JobSubmitter: number of splits:1
2026-02-06 19:59:28,997 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_local985853919_0001
2026-02-06 19:59:28,997 INFO mapreduce.JobSubmitter: Executing with tokens: []
2026-02-06 19:59:29,032 INFO mapreduce.Job: The url to track the job: http://localhost:8080/
2026-02-06 19:59:29,034 INFO mapreduce.Job: Running job: job_local985853919_0001
2026-02-06 19:59:29,037 INFO mapred.LocalJobRunner: OutputCommitter set in config null
2026-02-06 19:59:29,050 INFO output.PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
2026-02-06 19:59:29,051 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 2
2026-02-06 19:59:29,052 INFO output.FileOutputCommitter: FileOutputCommitter skip cleanup _temporary folders under output directory:false, ignore cleanup fa
ilures: false
2026-02-06 19:59:29,053 INFO mapred.LocalJobRunner: OutputCommitter is org.apache.hadoop.mapreduce.lib.output.FileOutputCommitter
2026-02-06 19:59:29,105 INFO mapred.LocalJobRunner: Waiting for map tasks
2026-02-06 19:59:29,106 INFO mapred.LocalJobRunner: Starting task: attempt_local985853919_0001_m_000000_0
2026-02-06 19:59:29,137 INFO output.PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
2026-02-06 19:59:29,137 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 2
2026-02-06 19:59:29,137 INFO output.FileOutputCommitter: FileOutputCommitter skip cleanup _temporary folders under output directory:false, ignore cleanup fa
ilures: false
2026-02-06 19:59:29,164 INFO mapred.Task: Using ResourceCalculatorProcessTree : [ ]
2026-02-06 19:59:29,169 INFO mapred.MapTask: Processing split: hdfs://localhost:9000/user/root/input/sample.txt:0+53
2026-02-06 19:59:29,301 INFO mapred.MapTask: (EQUATOR) 0 kwi 26214396(104857584)
2026-02-06 19:59:29,301 INFO mapred.MapTask: mapreduce.task.io.sort.mb: 100
2026-02-06 19:59:29,301 INFO mapred.MapTask: soft limit at 83886080
2026-02-06 19:59:29,301 INFO mapred.MapTask: bufstart = 0; bufvoid = 104857600
2026-02-06 19:59:29,301 INFO mapred.MapTask: kvstart = 26214396; length = 6553600
2026-02-06 19:59:29,307 INFO mapred.MapTask: Map output collector class = org.apache.hadoop.mapred.MapTask$MapOutputBuffer
2026-02-06 19:59:29,416 INFO mapred.LocalJobRunner:
2026-02-06 19:59:29,418 INFO mapred.MapTask: Starting flush of map output
2026-02-06 19:59:29,418 INFO mapred.MapTask: Spilling map output
2026-02-06 19:59:29,418 INFO mapred.MapTask: bufstart = 0; bufend = 105; bufvoid = 104857600
2026-02-06 19:59:29,418 INFO mapred.MapTask: kvstart = 26214396(104857584); kvend = 26214348(104857392); length = 49/6553600
2026-02-06 19:59:29,432 INFO mapred.MapTask: Finished spill 0
2026-02-06 19:59:29,444 INFO mapred.Task: attempt_local985853919_0001_m_000000_0 is done. And is in the process of committing
2026-02-06 19:59:29,449 INFO mapred.LocalJobRunner: map
2026-02-06 19:59:29,449 INFO mapred.Task: Task 'attempt_local985853919_0001_m_000000_0' done.
2026-02-06 19:59:29,457 INFO mapred.Task: Final Counters for attempt_local985853919_0001_m_000000_0: Counters: 24
File System Counters
```

Figure 1: Running WordCount MapReduce job

```
2026-02-06 19:59:29,457 INFO mapred.Task: Final Counters for attempt_local985853919_0001_m_000000_0: Counters: 24
File System Counters
  FILE: Number of bytes read=281533
  FILE: Number of bytes written=917318
  FILE: Number of read operations=0
  FILE: Number of large read operations=0
  FILE: Number of write operations=0
  HDFS: Number of bytes read=53
  HDFS: Number of bytes written=0
  HDFS: Number of read operations=5
  HDFS: Number of large read operations=0
  HDFS: Number of write operations=1
  HDFS: Number of bytes read erasure-coded=0
Map-Reduce Framework
  Map input records=2
  Map output records=13
  Map output bytes=105
  Map output materialized bytes=87
  Input split bytes=113
  Combine input records=13
  Combine output records=8
  Spilled Records=8
  Failed Shuffles=0
  Merged Map outputs=0
  GC time elapsed (ms)=4
  Total committed heap usage (bytes)=265289728
File Input Format Counters
  Bytes Read=53
2026-02-06 19:59:29,457 INFO mapred.LocalJobRunner: Finishing task: attempt_local985853919_0001_m_000000_0
2026-02-06 19:59:29,458 INFO mapred.LocalJobRunner: map task executor complete.
2026-02-06 19:59:29,462 INFO mapred.LocalJobRunner: Waiting for reduce tasks
2026-02-06 19:59:29,462 INFO mapred.LocalJobRunner: Starting task: attempt_local985853919_0001_r_000000_0
2026-02-06 19:59:29,472 INFO output.PathOutputCommitterFactory: No output committer factory defined, defaulting to FileOutputCommitterFactory
2026-02-06 19:59:29,472 INFO output.FileOutputCommitter: File Output Committer Algorithm version is 2
2026-02-06 19:59:29,472 INFO output.FileOutputCommitter: FileOutputCommitter skip cleanup _temporary folders under output directory:false, ignore cleanup fa
ilures: false
2026-02-06 19:59:29,473 INFO mapred.Task: Using ResourceCalculatorProcessTree : [ ]
2026-02-06 19:59:29,477 INFO mapred.ReduceTask: Using ShuffleConsumerPlugin: org.apache.hadoop.mapreduce.task.reduce.Shuffle@71cf769f
2026-02-06 19:59:29,479 WARN impl.MetricsSystemImpl: JobTracker metrics system already initialized!
2026-02-06 19:59:29,497 INFO reduce.MergeManagerImpl: MergerManager: memoryLimit=1441582208, maxSingleShuffleLimit=368395552, mergeThreshold=951444288, ioSo
rtFactor=10, memToMemMergeOutputsThreshold=10
```

Figure 2: WordCount in progress

```

2026-02-06 19:59:29,530 INFO reduce.LocalFetcher: localfetcher#1 about to shuffle output of map attempt_local905053919_0001_m_000000_0 decomp: 83 len: 87 to
MEMORY
2026-02-06 19:59:29,534 INFO reduce.InMemoryMapOutput: Read 83 bytes from map-output for attempt_local905053919_0001_m_000000_0
2026-02-06 19:59:29,537 INFO reduce.MergeManagerImpl: closeInMemoryFile -> map-output of size: 83, inMemoryMapOutputs.size() -> 1, commitMemory -> 0, usedMe
mory ->83
2026-02-06 19:59:29,540 INFO reduce.EventFetcher: EventFetcher is interrupted.. Returning
2026-02-06 19:59:29,541 INFO mapred.LocalJobRunner: 1 / 1 copied.
2026-02-06 19:59:29,541 INFO reduce.MergeManagerImpl: finalMerge called with 1 in-memory map-outputs and 0 on-disk map-outputs
2026-02-06 19:59:29,548 INFO mapred.Merger: Merging 1 sorted segments
2026-02-06 19:59:29,548 INFO mapred.Merger: Down to the last merge-pass, with 1 segments left of total size: 77 bytes
2026-02-06 19:59:29,551 INFO reduce.MergeManagerImpl: Merged 1 segments, 83 bytes to disk to satisfy reduce memory limit
2026-02-06 19:59:29,552 INFO reduce.MergeManagerImpl: Merging 1 files, 87 bytes from disk
2026-02-06 19:59:29,553 INFO reduce.MergeManagerImpl: Merging 0 segments, 0 bytes from memory into reduce
2026-02-06 19:59:29,553 INFO mapred.Merger: Merging 1 sorted segments
2026-02-06 19:59:29,554 INFO mapred.Merger: Down to the last merge-pass, with 1 segments left of total size: 77 bytes
2026-02-06 19:59:29,554 INFO mapred.LocalJobRunner: 1 / 1 copied.
2026-02-06 19:59:29,579 INFO Configuration.deprecation: mapred.skip.on is deprecated. Instead, use mapreduce.job.skiprecords
2026-02-06 19:59:29,636 INFO mapred.Task: Task:attempt_local905053919_0001_r_000000_0 is done. And is in the process of committing
2026-02-06 19:59:29,639 INFO mapred.LocalJobRunner: 1 / 1 copied
2026-02-06 19:59:29,639 INFO mapred.Task: Task:attempt_local905053919_0001_r_000000_0 is allowed to commit now
2026-02-06 19:59:29,653 INFO output.FileOutputCommitter: Saved output of task 'attempt_local905053919_0001_r_000000_0' to hdfs://localhost:9000/user/root/ou
tput
2026-02-06 19:59:29,654 INFO mapred.LocalJobRunner: reduce > reduce
2026-02-06 19:59:29,654 INFO mapred.Task: Task:attempt_local905053919_0001_r_000000_0 done.
2026-02-06 19:59:29,655 INFO mapred.Task: Final Counters for attempt_local905053919_0001_r_000000_0: Counters: 30
File System Counters
FILE: Number of bytes read=281739
FILE: Number of bytes written=917405
FILE: Number of read operations=0
FILE: Number of large read operations=0
FILE: Number of write operations=0
HDFS: Number of bytes read=53
HDFS: Number of bytes written=49
HDFS: Number of read operations=10
HDFS: Number of large read operations=0
HDFS: Number of write operations=3
HDFS: Number of bytes read erasure-coded=0
Map-Reduce Framework
Combine input records=0
Combine output records=0
Reduce input groups=8

```

Figure 3: WordCount in progress

```

Reduce input records=8
Reduce output records=8
Spilled Records=8
Shuffled Maps =1
Failed Shuffles=0
Merged Map outputs=1
GC time elapsed (ms)=0
Total committed heap usage (bytes)=265289728
Shuffle Errors
BAD_ID=0
CONNECTION=0
IO_ERROR=0
WRONG_LENGTH=0
WRONG_MAP=0
WRONG_REDUCE=0
File Output Format Counters
Bytes Written=49
2026-02-06 19:59:29,655 INFO mapred.LocalJobRunner: Finishing task: attempt_local905053919_0001_r_000000_0
2026-02-06 19:59:29,655 INFO mapred.LocalJobRunner: reduce task executor complete.
2026-02-06 19:59:30,060 INFO mapreduce.Job: Job job_local905053919_0001 running in uber mode : false
2026-02-06 19:59:30,060 INFO mapreduce.Job: map 100% reduce 100%
2026-02-06 19:59:30,067 INFO mapreduce.Job: Job job_local905053919_0001 completed successfully
2026-02-06 19:59:30,068 INFO mapreduce.Job: Counters: 36
File System Counters
FILE: Number of bytes read=563272
FILE: Number of bytes written=1834723
FILE: Number of read operations=0
FILE: Number of large read operations=0
FILE: Number of write operations=0
HDFS: Number of bytes read=106
HDFS: Number of bytes written=49
HDFS: Number of read operations=15
HDFS: Number of large read operations=0
HDFS: Number of write operations=4
HDFS: Number of bytes read erasure-coded=0
Map-Reduce Framework
Map input records=2
Map output records=13
Map output bytes=105
Map output materialized bytes=87
Input split bytes=113

```

Figure 4: WordCount in progress

```

Combine output records=8
Reduce input groups=8
Reduce shuffle bytes=87
Reduce input records=8
Reduce output records=8
Spilled Records=16
Shuffled Maps =1
Failed Shuffles=0
Merged Map outputs=1
GC time elapsed (ms)=4
Total committed heap usage (bytes)=530579456
Shuffle Errors
BAD_ID=0
CONNECTION=0
IO_ERROR=0
WRONG_LENGTH=0
WRONG_MAP=0
WRONG_REDUCE=0
File Input Format Counters
Bytes Read=53
File Output Format Counters
Bytes Written=49

```

Figure 5: WordCount in progress

```

root@LAPTOP-CPCUQN0J:~# hdfs dfs -ls /user/root/output
Found 2 items
-rw-r--r--  1 root supergroup          0 2026-02-06 19:59 /user/root/output/_SUCCESS
-rw-r--r--  1 root supergroup        49 2026-02-06 19:59 /user/root/output/part-r-00000

```

Figure 6: Reducer writing final WordCount output to HDFS

```

root@LAPTOP-CPCUQN0J:~# hdfs dfs -cat /user/root/output/part-r-00000
all      2
are      2
get      1
lucky    1
night    2
to       1
up       2
we       2

```

Figure 7: WordCount output in HDFS

1.2 Question 2: Mapper Input and Output

During the Map phase of the WordCount program, each line of input text is tokenized into individual words. For each occurrence of a word, the mapper emits a key–value pair where the key is the word and the value is the integer 1. ("we're", 1) ("up", 1) ("all", 1) ("night", 1) ("till", 1) ("the", 1) ("sun", 1) ...

Map input key type: LongWritable

Map input value type: Text

Map output key type: Text

Map output value type: IntWritable.

1.3 Question 3: Map Output Key–Value Pairs

After the Map phase finishes, Hadoop performs:

Shuffle: groups all values by key (word)

Sort: keys are sorted alphabetically

So all values for the same word are collected together.

so the input looks like ("we're", [1, 1, 1, 1]) ("up", [1, 1, 1, 1]) ("all", [1, 1, 1, 1]) ("night", [1, 1, 1, 1]) ("to", [1, 1]) ("get", [1, 1]) ("lucky", [1])

the types of key and vales of input of reduce is Key: Text Value: Iterable<IntWritable>, while that of output is Key: Text Value: IntWritable

1.4 Question 4: Shuffle and Sort Phase

```
public static class Map
    extends Mapper<LongWritable, Text, Text, IntWritable> {

    @Override
    public void map(LongWritable key, Text value, Context context)
        throws IOException, InterruptedException {

    public static class Reduce
        extends Reducer<Text, IntWritable, Text, IntWritable> {

    @Override
    public void reduce(Text key, Iterable<IntWritable> values, Context context)
        throws IOException, InterruptedException {

    job.setOutputKeyClass(Text.class);
    job.setOutputValueClass(IntWritable.class);
```

In the WordCount program, the Mapper class extends `Mapper<LongWritable, Text, Text, IntWritable>`, where the input key is the byte offset of each line and the input value is the line of text. The mapper emits intermediate key-value pairs of type `(Text, IntWritable)`.

The Reducer class extends `Reducer<Text, IntWritable, Text, IntWritable>`, where each key corresponds to a word and the values represent the counts emitted by the mapper. The reducer aggregates these values to produce the final word counts.

The output key and value classes of the job are set using `Text.class` and `IntWritable.class`.

1.5 Question 5: Reduce Phase

```
public void map(LongWritable key, Text value, Context context)
    throws IOException, InterruptedException {

    String line = value.toString().toLowerCase();

    // Remove punctuation
    line = line.replaceAll("[^a-z0-9 ]", " ");

    StringTokenizer tokenizer = new StringTokenizer(line);

    while (tokenizer.hasMoreTokens()) {
        Text word = new Text(tokenizer.nextToken());
        context.write(word, new IntWritable(1));
    }
}
```

The `map()` function processes one line of input at a time. The input value is first converted to lowercase to ensure case-insensitive counting. Punctuation is removed using the `replaceAll()` method with a regular expression. The cleaned line is then tokenized into individual words using a `StringTokenizer`. For each word, the mapper emits an intermediate key-value pair `(word, 1)` indicating one occurrence of the word.

1.6 Question 6: Error Detection

```
public void reduce(Text key, Iterable<IntWritable> values, Context context)
    throws IOException, InterruptedException {

    int sum = 0;

    for (IntWritable value : values) {
        sum += value.get();
    }

    context.write(key, new IntWritable(sum));
}
```

The `reduce()` function receives a key and a list of values associated with that key. Each key represents a unique word, and the values represent the counts emitted by the mapper. The reducer iterates over the list of values and computes their sum. Finally, it emits the word along with its total count as the output.

1.7 Question 7: WordCount on Large File (200.txt)

WordCount was executed on a larger dataset (200.txt) to analyze performance on larger input sizes.

Snapshots

```
root@LAPTOP-CPCUQN0J:~# hdfs dfs -ls /user/root/input
Found 2 items
-rw-r--r--  1 root supergroup      8312639 2026-02-07 00:33 /user/root/input/
200.txt
-rw-r--r--  1 root supergroup         53 2026-02-06 19:55 /user/root/input/
sample.txt
```

Figure 8: Uploading 200.txt to HDFS

```
2026-02-07 00:36:40 825 INFO mapped.LocalJobRunner: Finishing task: attempt_local656342458_0001_r_000000_0
2026-02-07 00:36:40 826 INFO mapped.LocalJobRunner: reduce task executor complete.
2026-02-07 00:36:49 798 INFO mapreduce.Job: map 100% reduce 100%
2026-02-07 00:36:49 798 INFO mapreduce.Job: Job job_local656342458_0001 completed successfully
2026-02-07 00:36:49 811 INFO mapreduce.Job: Counters: 36
File System Counters
  FILE: Number of bytes read=4804256
  FILE: Number of bytes written=8196247
  FILE: Number of read operations=0
  FILE: Number of large read operations=0
  FILE: Number of write operations=0
  HDFS: Number of bytes read=16625278
  HDFS: Number of bytes written=1574586
  HDFS: Number of read operations=15
  HDFS: Number of large read operations=0
  HDFS: Number of write operations=4
  HDFS: Number of bytes read erasure-coded=0
Map-Reduce Framework
  Map input records=146933
  Map output records=1348566
  Map output bytes=13455246
  Map output materialized bytes=2120579
  Input split bytes=110
  Combine input records=1348566
  Combine output records=139630
  Reduce input groups=139630
  Reduce shuffle bytes=2120579
  Reduce input records=139630
  Reduce output records=139630
  Spilled Records=279260
  Shuffled Maps=1
  Failed Shuffles=0
  Merged Map outputs=1
  GC time elapsed (ms)=40
  Total committed heap usage (bytes)=525336576
Shuffle Errors
  BAD_ID=0
  CONNECTION=0
  IO_ERROR=0
```

Figure 9: WordCount MapReduce job on 200.txt

```

WRONG_LENGTH=0
WRONG_MAP=0
WRONG_REDUCE=0
File Input Format Counters
  Bytes Read=8312639
File Output Format Counters
  Bytes Written=1574586

```

Figure 10: WordCount MapReduce job on 200.txt

```

root@LAPTOP-CPCUQN0J:~# hdfs dfs -ls /user/root/output_200
Found 2 items
-rw-r--r--  1 root supergroup          0 2026-02-07 00:36 /user/root/output_200/_SUCCESS
-rw-r--r--  1 root supergroup 1574586 2026-02-07 00:36 /user/root/output_200/part-r-000000

```

Figure 11: storing the wordcount output to output_200.txt

```

root@LAPTOP-CPCUQN0J:~# head output_200.txt
1
1
!!!Remember.      1
"                34
"100."           1
"A               1
"Alabama,"        1
"Albemarle"       2
"Albemarle,"      1
"Alceste,"        2

```

Figure 12: Merged WordCount output

1.8 Question 8: Replication Factor

Why don't directories have a replication factor?

In HDFS, replication is applied only to files because files are split into data blocks that are stored on DataNodes. Directories contain only metadata such as file names and permissions and do not store actual data blocks. Since there are no blocks to replicate, directories do not have a replication factor.

How does changing the replication factor impact performance?

Increasing the replication factor improves fault tolerance and read performance because data can be accessed from multiple DataNodes. However, it increases storage usage and slows down write operations due to additional replicas. Decreasing the replication factor reduces storage and write overhead but lowers fault tolerance.

Why does changing the replication factor affect performance?

Changing the replication factor affects performance because it determines how many copies of each data block are stored across the cluster. More replicas increase network and disk

usage during writes but enable parallel reads and higher reliability, while fewer replicas reduce overhead but increase the risk of data loss.

1.9 Question 9: Effect of Input Split Size

In this experiment, the WordCount program was executed twice on the same input dataset. In the first run, the default input split size was used. In the second run, the input split size was increased to 256 MB using the configuration property `mapreduce.input.fileinputformat.split.maxsize`.

Increasing the input split size reduces the number of input splits, which in turn reduces the number of mapper tasks created by Hadoop. As a result, the job execution time changes due to reduced task initialization and scheduling overhead. For small datasets, the difference in execution time is minimal, while for larger datasets, fewer mappers can lead to improved performance by lowering overhead.

The execution times observed in both runs demonstrate how input split size influences the parallelism and performance of a MapReduce job.

Snapshots

```
root@LAPTOP-CPCUQN0J:~# /usr/bin/time hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.3.6.jar wordcount /user/root/input /user/root/output_time
```

Figure 13: Running WordCount without input split size constraint

```
Bytes Written=1574586
15.15user 2.09system 0:08.69elapsed 198%CPU (0avgtext+0avgdata 396656maxresident)k
45288inputs+11960outputs (28major+110621minor)pagefaults 0swaps
```

Figure 14: Execution time and CPU usage without split optimization

```
root@LAPTOP-CPCUQN0J:~# /usr/bin/time hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.3.6.jar wordcount \
-D mapreduce.input.fileinputformat.split.maxsize=268435456 \
```

Figure 15: Running WordCount with custom input split size

```
WRONG_REDUCE=0
File Input Format Counters
  Bytes Read=8312639
File Output Format Counters
  Bytes Written=1574586
9.88user 1.61system 0:05.39elapsed 213%CPU (0avgtext+0avgdata 399100maxresident)k
96880inputs+11960outputs (131major+110850minor)pagefaults 0swaps
```

Figure 16: Execution time comparison showing performance difference

2 PySpark Experiments

**Due to the large size of the complete Project Gutenberg corpus, a representative subset of Gutenberg texts was used for analysis. This subset preserves the original Gutenberg metadata format and is sufficient to demonstrate metadata extraction, TF-IDF similarity computation, and author influence analysis.*

2.1 Question 10: Metadata Extraction

Metadata fields such as language appear only once per book in Project Gutenberg texts. Since the dataset was loaded line-by-line, most rows do not contain metadata values. Therefore,

rows with non-empty metadata fields were filtered and deduplicated by file name to obtain one metadata record per book before analysis.

To find the most common language, metadata rows containing non-empty language values were filtered and deduplicated per book. The dataset was then grouped by language and ordered by count in descending order. English was found to be the most common language among the analyzed books.

Snapshots

```
root@LAPTOP-CPCUQN0J:~/gutenberg# ls
11-0.txt 1342-0.txt 1661-0.txt 84-0.txt 98-0.txt
root@LAPTOP-CPCUQN0J:~/gutenberg# |
```

Figure 17: Loading Gutenberg dataset

```
>>> books_df.printSchema()
root
 |-- text: string (nullable = true)
 |-- file_name: string (nullable = false)
```

Figure 18: Inspecting DataFrame Schema

```
>>> books_df.show(5, truncate=False)
+-----+-----+
|text|file_name|
+-----+-----+
|The Project Gutenberg eBook of A Tale of Two Cities, by Charles Dickens|file:///root/gutenberg/98-0.txt|
|This eBook is for the use of anyone anywhere in the United States and|file:///root/gutenberg/98-0.txt|
|most other parts of the world at no cost and with almost no restrictions|file:///root/gutenberg/98-0.txt|
|whatsoever. You may copy it, give it away or re-use it under the terms|file:///root/gutenberg/98-0.txt|
+-----+-----+
only showing top 5 rows
```

Figure 19: Previewing Loaded Text Data

```
>>> from pyspark.sql.functions import regexp_extract
books_df \
>>>
>>> metadata_raw = books_df \
...   .withColumn("title", regexp_extract("text", r"Title:\s*(.*)", 1)) \
...   .withColumn("author", regexp_extract("text", r"Author:\s*(.*)", 1)) \
...   .withColumn("release_date", regexp_extract("text", r"Release Date:\s*(.*)", 1)) \
...   .withColumn("language", regexp_extract("text", r"Language:\s*(.*)", 1)) \
...   .withColumn("encoding", regexp_extract("text", r"Character set encoding:\s*(.*)", 1))
>>> from pyspark.sql.functions import max
df = metadata_raw
>>> metadata_df = metadata_raw.groupBy("file_name").agg(
...   max("title").alias("title"),
...   max("author").alias("author"),
...   max("release_date").alias("release_date"),
...   max("language").alias("language"),
...   max("encoding").alias("encoding")
... )
>>>
>>> metadata_df.show(truncate=False)
+-----+-----+-----+-----+-----+-----+
|file_name|title|author|release_date|language|encoding|
+-----+-----+-----+-----+-----+-----+
|file:///root/gutenberg/11-0.txt|The Adventures of Sherlock Holmes|Arthur Conan Doyle|November 29, 2002 [eBook #1661]|English|UTF-8|
|file:///root/gutenberg/1342-0.txt|The Adventures of Sherlock Holmes|Arthur Conan Doyle|November 29, 2002 [eBook #1661]|English|UTF-8|
|file:///root/gutenberg/1661-0.txt|The Adventures of Sherlock Holmes|Arthur Conan Doyle|November 29, 2002 [eBook #1661]|English|UTF-8|
|file:///root/gutenberg/84-0.txt|A Tale of Two Cities|Charles Dickens|January, 1994 [eBook #98]|English|UTF-8|
|file:///root/gutenberg/98-0.txt|A Tale of Two Cities|Charles Dickens|January, 1994 [eBook #98]|English|UTF-8|
+-----+-----+-----+-----+-----+-----+
```

Figure 20: Metadata Extraction Using Regular Expressions

```
>>> books_per_year.show(truncate=False)
+-----+-----+
|year|count|
+-----+-----+
|1994|1    |
|2002|1    |
+-----+-----+
```

Figure 21: number of books released each year

```
>>> language_per_book.groupBy("language") \
  rBy("count", asc...) \
  ... .orderBy("count", ascending=False) \
  ... .show(1, truncate=False)
+-----+-----+
|language|count|
+-----+-----+
|English |2    |
+-----+-----+
```

Figure 22: Most common language

```
>>> from pyspark.sql.functions import length, avg
red.select(avg(length("title"))).show()
>>>
>>> metadata_df_filtered.select(avg(length("title"))).show()
+-----+
|avg(length(title))|
+-----+
|          13.25|
+-----+
```

Figure 23: Average title length

2.2 Question 11: TF-IDF and Cosine Similarity

TF-IDF vectors were computed for each book, and cosine similarity was used to identify similar documents.

Snapshots

```
>>> from pyspark.sql.functions import lower, regexp_replace, split, explode
>>> clean_df = books_df.withColumn(
...     lower(lower("text... "clean_text",
...     regexp_replace(lower("text"), "[^a-z\\s]", "")
... )
>>> words_df = clean_df.withColumn(
...     explode(split("c... "word",
...     explode(split("clean_text", "\\s+"))
... )
>>> words_df = words_df.filter(words_df.word != "")
>>> words_df.select("file_name", "word").show(10, truncate=False)
[Stage 3:> (0 + 1)
```

file_name	word
file:///root/gutenberg/98-0.txt	the
file:///root/gutenberg/98-0.txt	project
file:///root/gutenberg/98-0.txt	gutenberg
file:///root/gutenberg/98-0.txt	ebook
file:///root/gutenberg/98-0.txt	of
file:///root/gutenberg/98-0.txt	a
file:///root/gutenberg/98-0.txt	tale
file:///root/gutenberg/98-0.txt	of
file:///root/gutenberg/98-0.txt	two
file:///root/gutenberg/98-0.txt	cities

only showing top 10 rows

Figure 24: Text cleaning and tokenization

```
>>> tf_df = words_df.groupBy("file_name", "word").count()
>>> tf_df = tf_df.withColumnRenamed("count", "tf")
>>> tf_df.show(10, truncate=False)
[Stage 4:> (0 + 5) [Stage 4:=====> (4 + 1)
```

file_name	word	tf
file:///root/gutenberg/98-0.txt	age	128
file:///root/gutenberg/98-0.txt	us	114
file:///root/gutenberg/98-0.txt	jaw	2
file:///root/gutenberg/98-0.txt	christian	6
file:///root/gutenberg/98-0.txt	about	169
file:///root/gutenberg/98-0.txt	blunderbusses	1
file:///root/gutenberg/98-0.txt	pilferer	1
file:///root/gutenberg/98-0.txt	look	100
file:///root/gutenberg/98-0.txt	tinderbox	1
file:///root/gutenberg/98-0.txt	quieted	1

only showing top 10 rows

Figure 25: Term Frequency (TF)

```
>>> from pyspark.sql.functions import countDistinct, log
>>> num_docs = books_df.select("file_name").distinct().count()
>>> df_df = tf_df.groupBy("word").agg(countDistinct("file_name").alias("df"))
>>> idf_df = df_df.withColumn("idf", log(num_docs / df_df.df))
>>> idf_df.show(10, truncate=False)
```

word	df	idf
superseded	2	0.9162907318741551
connected	4	0.22314355131420976
knuckled	1	1.6094379124341003
spoiling	1	1.6094379124341003
filing	1	1.6094379124341003
few	5	0.0
imitation	3	0.5108256237659907
importantno	1	1.6094379124341003
biting	2	0.9162907318741551
still	5	0.0

only showing top 10 rows

Figure 26: Inverse Document Frequency (IDF)

```
>>> tfidf_df = tf_df.join(idf_df, on="word")
>>> tfidf_df = tfidf_df.withColumn("tfidf", tfidf_df.tf * tfidf_df.idf)
>>> tfidf_df.select("file_name", "word", "tfidf").show(10, truncate=False)
```

file_name	word	tfidf
file:///root/gutenberg/1342-0.txt	superseded	0.9162907318741551
file:///root/gutenberg/98-0.txt	superseded	0.9162907318741551
file:///root/gutenberg/84-0.txt	connected	1.5620048591994684
file:///root/gutenberg/1661-0.txt	connected	1.5620048591994684
file:///root/gutenberg/1342-0.txt	connected	3.3471532697131465
file:///root/gutenberg/98-0.txt	connected	1.7851484105136781
file:///root/gutenberg/98-0.txt	knuckled	3.2188758248682006
file:///root/gutenberg/98-0.txt	spoiling	1.6094379124341003
file:///root/gutenberg/98-0.txt	filing	1.6094379124341003
file:///root/gutenberg/11-0.txt	few	0.0

only showing top 10 rows

Figure 27: TF-IDF computation

```
>>> similarity_df.orderBy("cosine_similarity", ascending=False).show(10, truncate=False)
[Stage 28:> (0 + 5) / 5][Stage 29:> (0 + 5) [Stage 28:=====] (2 + 3)
```

book2	book1	dot_product	norm1	norm2	cosine_similarity
file:///root/gutenberg/84-0.txt	file:///root/gutenberg/1342-0.txt	55174.627074063894	1298.844436778923	301.323449786551	0.1409773481353914
file:///root/gutenberg/1342-0.txt	file:///root/gutenberg/84-0.txt	55174.627074063894	301.323449786551	1298.844436778923	0.1409773481353914
file:///root/gutenberg/98-0.txt	file:///root/gutenberg/84-0.txt	13010.374020895459	301.323449786551	1103.784835493392	0.039117620378181256
file:///root/gutenberg/84-0.txt	file:///root/gutenberg/98-0.txt	13010.374020895459	1103.784835493392	301.323449786551	0.039117620378181256
file:///root/gutenberg/98-0.txt	file:///root/gutenberg/1661-0.txt	33611.00757956753	846.4537493728855	1103.784835493392	0.035974426202866956
file:///root/gutenberg/1661-0.txt	file:///root/gutenberg/98-0.txt	33611.00757956753	1103.784835493392	846.4537493728855	0.035974426202866956
file:///root/gutenberg/1342-0.txt	file:///root/gutenberg/98-0.txt	39562.94041705865	1103.784835493392	1298.844436778923	0.027596654901981797
file:///root/gutenberg/98-0.txt	file:///root/gutenberg/1342-0.txt	39562.94041705865	1298.844436778923	1103.784835493392	0.027596654901981797
file:///root/gutenberg/1661-0.txt	file:///root/gutenberg/84-0.txt	6515.813851077589	301.323449786551	846.4537493728855	0.025546564503745955
file:///root/gutenberg/84-0.txt	file:///root/gutenberg/1661-0.txt	6515.813851077589	846.4537493728855	301.323449786551	0.025546564503745955

only showing top 10 rows

Figure 28: Cosine Similarity Between Documents

2.3 Question 12: Author Influence Network

To construct the author influence network, author-year metadata was duplicated with renamed columns to avoid ambiguity during self-joins. A directed edge was created from a source author to a target author when the source author's publication year was earlier than the target author's year. This temporal ordering models potential literary influence between authors.

Snapshots

```
>>> author_year_df.show(truncate=False)
```

file_name	author	year
file:///root/gutenberg/1661-0.txt	Arthur Conan Doyle	2002
file:///root/gutenberg/98-0.txt	Charles Dickens	1994

Figure 29: Extracted author and year metadata

```
>>> influence_df.show(truncate=False)
+-----+-----+-----+-----+
|source_author|source_year|target_author|target_year|
+-----+-----+-----+-----+
|Charles Dickens|1994|Arthur Conan Doyle|2002|
+-----+-----+-----+-----+
```

Figure 30: Author influence analysis

3 Conclusion

This assignment provided hands-on experience with Hadoop MapReduce and Apache Spark for large-scale text analytics. The experiments demonstrated distributed storage, parallel computation, and advanced analytics.