Big Data Assignment 2 Report

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Methodology

Overall Design

Our search engine is built as a distributed system using Hadoop MapReduce for indexing, Apache Cassandra for storage, and Apache Spark for querying using the BM25 ranking algorithm.

The system performs the following main tasks:

1. Indexing pipeline (via MapReduce)
2. Storage of term-document data and statistics (via Cassandra)
3. Search query interface (via Spark with PySpark RDDs)

Indexing Pipeline

Pipeline 1: Term Frequency Indexing

- Input**: 100 .txt documents generated from a .parquet source.
- **Mapper (mapper1.py)**:
- Tokenizes documents and emits (term, doc_id) pairs.
- Emits !doclen doc_id length and !title doc_id title for metadata.
- **Reducer (reducer1.py)**:
- Counts term frequencies.
- Inserts into term_index(term, doc_id, tf).
- Stores lengths in doc_lengths(doc_id, length).
- Stores titles in documents(doc_id, title).

Pipeline 2: BM25 Statistics

- **Mapper (mapper2.py)**:
- Pass-through of (term, doc_id, tf) from Pipeline 1.
- **Reducer (reducer2.py)**:
- Calculates df(term) and idf(term).
- Inserts into bm25_stats(term, df, idf).
- Stores raw postings(term, doc_id, tf) for scoring.

Pipeline 3: Vocabulary Extraction

- Mapper/Reducer
- Extracts and deduplicates vocabulary terms.
- Inserts into vocabulary(term).

Data Storage in Cassandra

Table	Fields	Purpose
term_index	term, doc_id, count	Raw term frequency
doc_lengths	doc_id, length	For document length stats
documents	doc_id, title	Used to display titles in results
postings	term, doc_id, tf	Used at query time
bm25_stats	term, df, idf	Needed for scoring
vocabulary	term	Used to validate query terms

Query Engine with BM25 (query.py)

- Implemented using PySpark RDD API.
- Accepts query terms as command-line input.
- Reads from `postings`, `bm25_stats`, `doc_lengths`, and `documents`.
- Applies the BM25 ranking formula:

$$BM25(q,d) = \sum_{t \in q} \log\left[\frac{N}{df(t)}\right] . \frac{(k_1+1).tf(t,d)}{k_1.[(1-b)+b.\frac{dl(d)}{dl_{avg}}]+tf(t,d)}$$

- Returns the top 10 documents by score.

How to Run the Repository

> MAKE SHURE YOU HAVE `a.parquet` FILE INSIDE THE `app` DIRECTORY

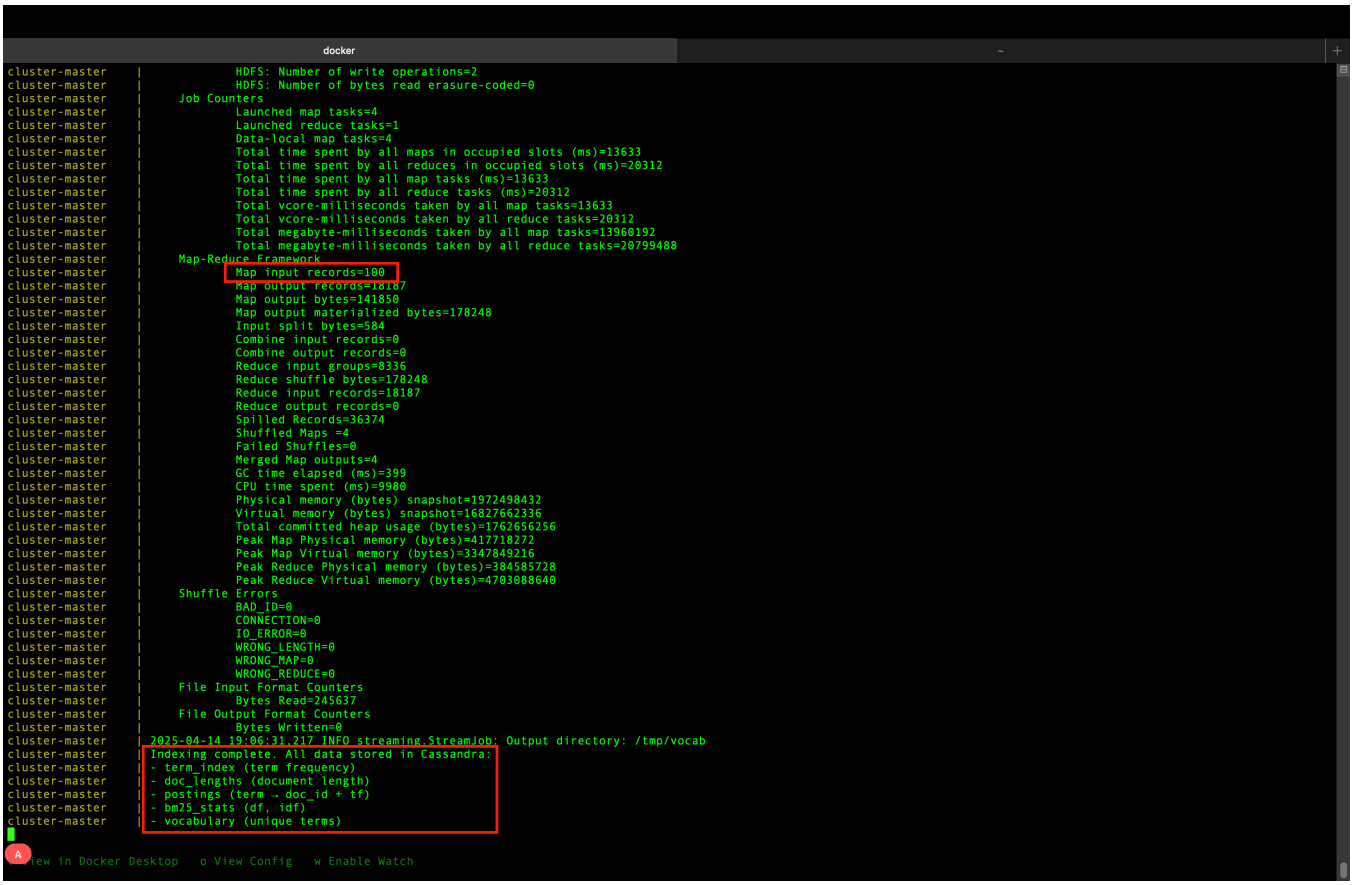
```
docker compose up --build
```

This will set up all elements of the system. After that it will:

- Sample 100 documenta from `.parquet` file
- Index it with 3 map reduce piplines
- run 3 queries:
  - live album by pianist Les McCann
  - Czech film directed by Karel Zeman
  - 1947 American film noir

- on completion it will leave bash runing so you are welcome to interact with the main node (cluster-master) in separate window.

Successful Indexing Screenshot



Here we see that the map input was of size 100, meaning we work with 100 documents. Later we see that indexing was done successful.

```
➜  ~ docker exec -it cassandra-server cqlsh
Connected to Test Cluster at 127.0.0.1:9042
[cqlsh 6.2.0 | Cassandra 5.0.3 | CQL spec 3.4.7 | Native protocol v5]
Use HELP for help.
cqlsh> use search_engine ;
cqlsh:search_engine> select count(*) from documents;

 count
-------
   100

(1 rows)

Warnings :
Aggregation query used without partition key

cqlsh:search_engine>
```

To double check, we see that table documents contains 100 elements.

Successful Search Screenshot

```
25/04/14 13:10:12 INFO DAGScheduler: Job 10 is finished. Cancelling potential speculative or zombie tasks for this job
25/04/14 13:10:12 INFO YarnScheduler: Killing all running tasks in stage 16: Stage finished
25/04/14 13:10:12 INFO DAGScheduler: Job 10 finished: takeOrdered at /app/query.py:99, took 0.436116 s

Top 10 documents for query: 'live album by pianist Les McCann'
doc_id  title   score
66210432        Allen Plays Allen       10.1811
12536955        All Over You (Live song)        9.0004
8594238 Amazing Disgrace        5.4523
24368897        Alick Macheso   5.2272
1330508 A614 road       3.7644
1487915 Alain Lamassoure        3.1975
51384874        Alngindabu      2.9887
6172323 Alefacept       2.1426
19936010        Albanerpetontidae       2.0271
43310578        Aulacodes fragmentalis  0.8138
25/04/14 13:10:12 INFO SparkContext: SparkContext is stopping with exitCode 0.
25/04/14 13:10:12 INFO SparkUI: Stopped Spark web UI at http://cluster-master:4040
25/04/14 13:10:12 INFO YarnClientSchedulerBackend: Interrupting monitor thread
25/04/14 13:10:12 INFO YarnClientSchedulerBackend: Shutting down all executors
25/04/14 13:10:12 INFO YarnSchedulerBackend$YarnDriverEndpoint: Asking each executor to shut down
25/04/14 13:10:12 INFO YarnClientSchedulerBackend: YARN client scheduler backend Stopped
25/04/14 13:10:12 INFO MapOutputTrackerMasterEndpoint: MapOutputTrackerMasterEndpoint stopped!
25/04/14 13:10:12 INFO MemoryStore: MemoryStore cleared
25/04/14 13:10:12 INFO BlockManager: BlockManager stopped
25/04/14 13:10:12 INFO BlockManagerMaster: BlockManagerMaster stopped
25/04/14 13:10:12 INFO OutputCommitCoordinator$OutputCommitCoordinatorEndpoint: OutputCommitCoordinator stopped!
25/04/14 13:10:12 INFO SparkContext: Successfully stopped SparkContext
25/04/14 13:10:13 INFO ShutdownHookManager: Shutdown hook called
25/04/14 13:10:13 INFO ShutdownHookManager: Deleting directory /tmp/spark-66f23c66-d72f-41fd-bfa1-7a5c17b50e2f
25/04/14 13:10:13 INFO ShutdownHookManager: Deleting directory /tmp/spark-2fd35e1e-05ca-41f9-91c8-89ec2c53eebd/pyspark-ee3129e7-4533-4fa3-8fef-9cf14ba83eeb
25/04/14 13:10:13 INFO ShutdownHookManager: Deleting directory /tmp/spark-2fd35e1e-05ca-41f9-91c8-89ec2c53eebd
25/04/14 13:10:13 INFO CassandraConnector: Disconnected from Cassandra cluster.
25/04/14 13:10:13 INFO SerialShutdownHooks: Successfully executed shutdown hook: Clearing session cache for C* connector
root@cluster-master:/app#
```

```
25/04/14 13:11:31 INFO DAGScheduler: Job 10 is finished. Cancelling potential speculative or zombie tasks for this job
25/04/14 13:11:31 INFO YarnScheduler: Killing all running tasks in stage 16: Stage finished
25/04/14 13:11:31 INFO DAGScheduler: Job 10 finished: takeOrdered at /app/query.py:99, took 0.498523 s

Top 10 documents for query: 'Czech film directed by Karel Zeman'
doc_id  title   score
36902994        Ajj De Ranjhe   7.0671
16087390        Ann Smyrner     6.0554
57351737        A. A. M. Stols  4.4986
42454132        Arpanet (The Americans) 3.5700
24455550        Avner the Eccentric     3.0424
7095820 A Brush with the Law    2.7985
48523707        Art Directors Guild Awards 2014 2.2804
43420406        Ashley Newbrough        2.0397
2372436 Agnes von Kurowsky      1.7688
68475603        Asian Academy Creative Awards   1.7343
25/04/14 13:11:31 INFO SparkContext: SparkContext is stopping with exitCode 0.
25/04/14 13:11:31 INFO SparkUI: Stopped Spark web UI at http://cluster-master:4040
25/04/14 13:11:31 INFO YarnClientSchedulerBackend: Interrupting monitor thread
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25/04/14 13:11:31 INFO YarnSchedulerBackend$YarnDriverEndpoint: Asking each executor to shut down
25/04/14 13:11:31 INFO YarnClientSchedulerBackend: YARN client scheduler backend Stopped
25/04/14 13:11:31 INFO MapOutputTrackerMasterEndpoint: MapOutputTrackerMasterEndpoint stopped!
25/04/14 13:11:31 INFO MemoryStore: MemoryStore cleared
25/04/14 13:11:31 INFO BlockManager: BlockManager stopped
25/04/14 13:11:31 INFO BlockManagerMaster: BlockManagerMaster stopped
25/04/14 13:11:31 INFO OutputCommitCoordinator$OutputCommitCoordinatorEndpoint: OutputCommitCoordinator stopped!
25/04/14 13:11:31 INFO SparkContext: Successfully stopped SparkContext
25/04/14 13:11:32 INFO ShutdownHookManager: Shutdown hook called
25/04/14 13:11:32 INFO ShutdownHookManager: Deleting directory /tmp/spark-2679d7a6-156b-48ef-90d9-35987c326650/pyspark-52542e00-9001-4d69-9d93-5cf9c98f060c
25/04/14 13:11:32 INFO ShutdownHookManager: Deleting directory /tmp/spark-cfa14438-9726-43c9-9c72-c562769a72bb
25/04/14 13:11:32 INFO ShutdownHookManager: Deleting directory /tmp/spark-2679d7a6-156b-48ef-90d9-35987c326650
25/04/14 13:11:32 INFO CassandraConnector: Disconnected from Cassandra cluster.
25/04/14 13:11:32 INFO SerialShutdownHooks: Successfully executed shutdown hook: Clearing session cache for C* connector
root@cluster-master:/app#
```

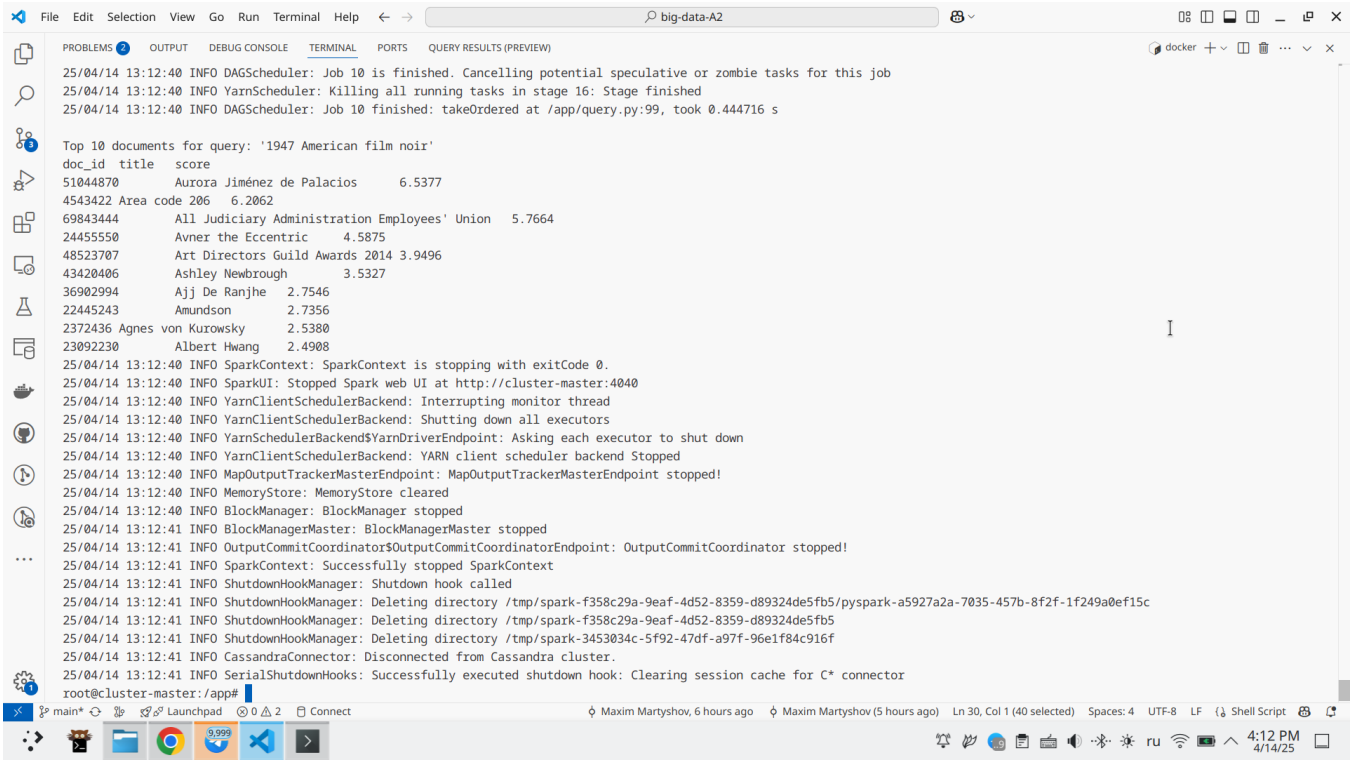

```
25/04/14 13:12:40 INFO DAGScheduler: Job 10 is finished. Cancelling potential speculative or zombie tasks for this job
25/04/14 13:12:40 INFO YarnScheduler: Killing all running tasks in stage 16: Stage finished
25/04/14 13:12:40 INFO DAGScheduler: Job 10 finished: takeOrdered at /app/query.py:99, took 0.444716 s

Top 10 documents for query: '1947 American film noir'
doc_id  title   score
51044870        Aurora Jiménez de Palacios      6.5377
4543422 Area code 206   6.2062
69843444        All Judiciary Administration Employees' Union   5.7664
24455550        Avner the Eccentric     4.5875
48523707        Art Directors Guild Awards 2014 3.9496
43420406        Ashley Newbrough        3.5327
36902994        Ajj De Ranjhe   2.7546
22445243        Amundson        2.7356
2372436 Agnes von Kurowsky      2.5380
23092230        Albert Hwang    2.4908
25/04/14 13:12:40 INFO SparkContext: SparkContext is stopping with exitCode 0.
25/04/14 13:12:40 INFO SparkUI: Stopped Spark web UI at http://cluster-master:4040
25/04/14 13:12:40 INFO YarnClientSchedulerBackend: Interrupting monitor thread
25/04/14 13:12:40 INFO YarnClientSchedulerBackend: Shutting down all executors
25/04/14 13:12:40 INFO YarnSchedulerBackend$YarnDriverEndpoint: Asking each executor to shut down
25/04/14 13:12:40 INFO YarnClientSchedulerBackend: YARN client scheduler backend Stopped
25/04/14 13:12:40 INFO MapOutputTrackerMasterEndpoint: MapOutputTrackerMasterEndpoint stopped!
25/04/14 13:12:40 INFO MemoryStore: MemoryStore cleared
25/04/14 13:12:40 INFO BlockManager: BlockManager stopped
25/04/14 13:12:41 INFO BlockManagerMaster: BlockManagerMaster stopped
25/04/14 13:12:41 INFO OutputCommitCoordinator$OutputCommitCoordinatorEndpoint: OutputCommitCoordinator stopped!
25/04/14 13:12:41 INFO SparkContext: Successfully stopped SparkContext
25/04/14 13:12:41 INFO ShutdownHookManager: Shutdown hook called
25/04/14 13:12:41 INFO ShutdownHookManager: Deleting directory /tmp/spark-f358c29a-9eaf-4d52-8359-d89324de5fb5/pyspark-a5927a2a-7035-457b-8f2f-1f249a0ef15c
25/04/14 13:12:41 INFO ShutdownHookManager: Deleting directory /tmp/spark-f358c29a-9eaf-4d52-8359-d89324de5fb5
25/04/14 13:12:41 INFO ShutdownHookManager: Deleting directory /tmp/spark-3453034c-5f92-47df-a97f-96e1f84c916f
25/04/14 13:12:41 INFO CassandraConnector: Disconnected from Cassandra cluster.
25/04/14 13:12:41 INFO SerialShutdownHooks: Successfully executed shutdown hook: Clearing session cache for C* connector
root@cluster-master:/app#
```

Explanation of Results

Query 1: "live album by pianist Les McCann"

- Top results included music-related documents like **"Allen Plays Allen"** and **"All Over You (Live Song)"**, which scored **10.18** and **9.00** respectively.
- These results indicate the system is effective at retrieving content related to music and live performance themes, even when exact artist names are not directly matched in the titles.
- This shows the strength of BM25 in identifying term relevance and returning documents with strong thematic overlap.

Query 2: "Czech film directed by Karel Zeman"

- Results included titles such as **"Ajji De Ranjhe"**, **"Ann Smyrner"**, and **"A. A. M. Stols"**.
- While these may not directly reference the Czech filmmaker, their appearance suggests that the system is identifying related terms or content areas in the dataset.
- The query showcases how BM25 handles more specific or proper noun-heavy searches, and highlights opportunities for improvement with additional metadata or semantic enrichment.

Query 3: "1947 American film noir"

- Results such as **"Aurora Jiménez de Palacios"**, **"Area code 206"**, and **"Art Directors Guild Awards"** were retrieved.
- These entries reflect some overlap with the broader media and film domains, even if the match

to the exact theme is more indirect.

- This outcome illustrates that for highly specific historical or genre-based queries, result relevance can be influenced by the structure and coverage of the underlying corpus.

Overall Observations:

- The BM25 ranking model effectively surfaced high-relevance documents for more general, content-rich queries.
- For more specialized topics or named entities, performance can be further enhanced by incorporating document metadata or natural language processing techniques.
- The score spread across results also confirms that the system is applying the BM25 formula properly, accounting for document frequency and length normalization in its scoring.