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Big Data Analytics on NYC Taxi Transportation Data

Part 2: MapReduce & Visualisation Analysis

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1. Introduction

Traditional data processing techniques are no longer adequate due to the exponential growth in data in the transportation sector. The second stage of a Big Data project that uses **Hadoop MapReduce** and **data visualisation** tools to analyse the **New York City Yellow Taxi Trip dataset** is presented in this project. The objective is to derive

practical insights that can guide business choices about transportation planning and urban mobility.

1.1 Background and Context

NYC's taxi system generates millions of trip records daily. Analysing this data requires Big Data technologies like MapReduce, which splits tasks into:

- **Map phase**: filtering and transformation
- **Reduce phase**: aggregation and summarization

1.2 Project Objectives

- Implement MapReduce algorithms
- Process large-scale taxi data
- Create meaningful visualisations
- Apply Big Data concepts
- Extract business value

2. Hadoop Overview and Setup

2.1 What is Hadoop?

Apache Hadoop is an open-source framework designed for the distributed storage and processing of large datasets across clusters of computers. It follows the **MapReduce programming model**, which splits tasks into two main phases:

- **Map Phase:** Processes and filters input data into key-value pairs.
- **Reduce Phase:** Aggregates and summarises the mapped data.

Hadoop is highly scalable and fault-tolerant, making it ideal for handling **Volume**, **Velocity**, and **Variety**—three of the core Vs of Big Data.

2.2 Local Hadoop Setup

To simulate a distributed environment locally, I set up a **single-node Hadoop cluster** on my machine using the following steps:

1. Installed Java (required for Hadoop runtime).
    - Download the Java installation file
    - Create a folder under the C drive and install Java directly into the Java folder created.
    - Cut and paste jdk folder in the Program Files into the Java folder created. Delete the Java folder under Program Files
    - configure Java environment - env. var. --> name: `JAVA_HOME`, value: `C:\Java\jdk1.8.0_*\bin` copied path from bin folder under Java
    - configure system variables, edit `path` and create new variable - paste: `C:\Java\jdk1.8.0_*\bin` done
    - check by running `java` on CLI
2. Downloaded and configured.
    - download `hadoop-3.4.2.tar`, unzip, copy it to the C drive and rename it to `Hadoop`
    - in etc folder, edit `hadoop-env` to paste `C:\Java\jdk1.8.0_*\bin`, resulting in `set JAVA_HOME=C:\Java\jdk1.8.0_*\bin`
    - configure Java environment - env. var. --> name: `HADOOP_HOME`, value: `C:\hadoop\bin` copied path from bin folder under Java
    - configure system variables, edit `path` and create new variable - paste: `C:\hadoop\bin` and `C:\hadoop\sbin` done
    - check by running `hadoop` on CLI
3. Set configurations for Hadoop to run on our system
    - got to `hadoop -> etc -> hadoop` folder to edit `core-site.xml` file
    - add property with name and value

```
<configuration>
<property>
  <name>fs.defaultFS</name>
  <value>hdfs://localhost:8020</value>
</property>
</configuration>
```

    - got to `hadoop -> etc -> hadoop` folder to edit `httpfs-site.xml` file

- add property with name and value

```
 <configuration>
 <property>
   <name>dfs.replication</name>
   <value>1</value>
 </property>
<property>
   <name>dfs.namenode.name.dir</name>
   <value>C:\hadoop\data\namenode</value>
 </property>
<property>
   <name>dfs.datanode.name.dir<</name>
   <value>C:\hadoop\data\datanode</value>
 </property>
 </configuration>
```

- create `data` folder and `namenode` & `datanode` inside it
- go to `etc` -> `hadoop` to edit `mapred-site.xml`

```
 <configuration>
 <property>
 <name>mapreduce.framework.name</name>
 <value>yarn</value>
 </property>
 <property>
 <name>mapreduce.map.java.opts</name>
 <value>-Xmx4096m</value>
 </property>
 <property>
 <name>mapreduce.reduce.java.opts</name>
 <value>Xmx6144m</value>
 </property>
 </configuration>
```

- go to `etc` -> `hadoop` to edit `yarn-site.xml`

```
 <configuration>
 <property>
   <name>yarn.nodemanager.aux-services</name>
   <value>mapreduce_shuffle</value>
 </property>
<property>
   <name>yarn.nodemanager.auxservices.shuffle.class</name>
   <value>org.apache.hadoop.mapred.ShuffleHandler</value>
 </property>
 </configuration>
```

4. Fixed `bin` folder to run on Windows

- Delete the `bin` folder inside the `hadoop` folder
- Download the new bin folder `https://drive.google.com/file/d/1nCN_jK7EJF2DmPUUxgOggnvJ6k6tksYz/view` and paste it inside the `hadoop` folder
- Run `winutils.exe` file - it will suggest to download `MSVCR120.dll` file and paste the file inside `C://Windows/System32/` folder

5. Download and install the `C++ redistributable` for Visual Studio

6. Format `namenode`

```
hdfs namenode -format
```

Look for `name node successfully formatted`

7. Launch `Hadoop` cluster

- in root directory, run `cd sbin`, i.e. `C:hadoop\sbin`
- start `Hadoop` cluster: `namenode` and `datanode`

```
start-dfs.cmd
```

- start `resource manager`

```
start-yarn.cmd
```

- check on `localhost:9870`
- check cluster size and number of nodes: `localhost:80888`
- stop all nodes

```
stop-all.cmd
```

5. Created HDFS directories and uploaded the dataset

```
hdfs dfs -mkdir -p /nyc_tlc_data
hdfs dfs -put green_taxi_combined.csv /nyc_tlc_data
```

This setup enabled me to run Python-based MapReduce jobs using Hadoop Streaming.

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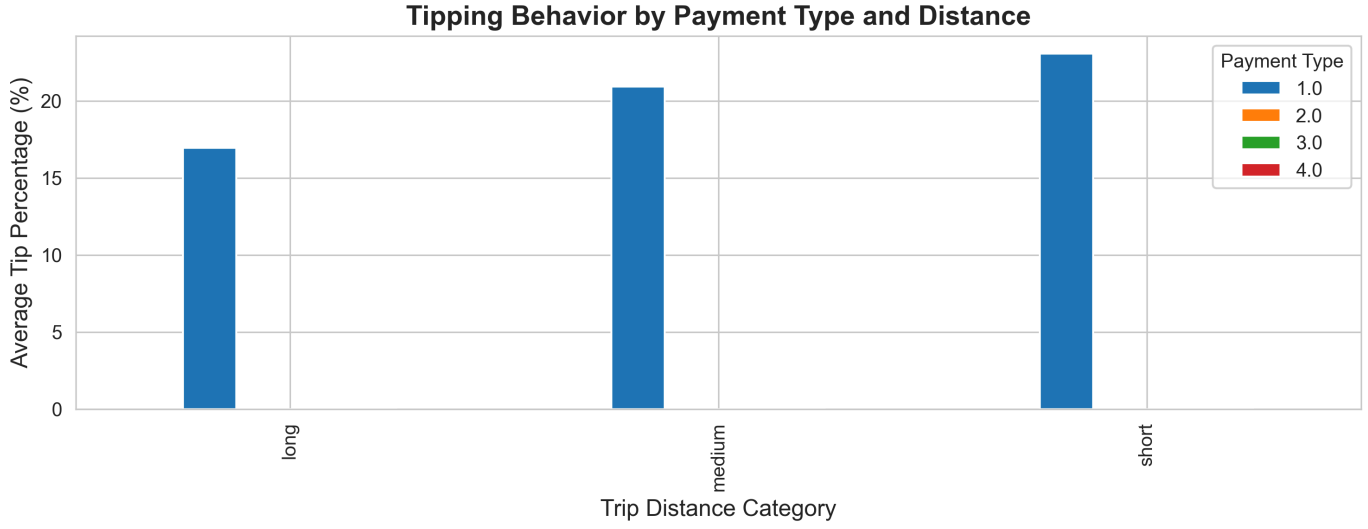
3. Visualisations and Their Value

After processing the dataset using MapReduce, I created two key visualisations to effectively communicate the insights.

3.1 Tipping Behaviour

Visualisation: Grouped bar chart showing average tip percentage by payment type and trip distance category (short, medium, long).

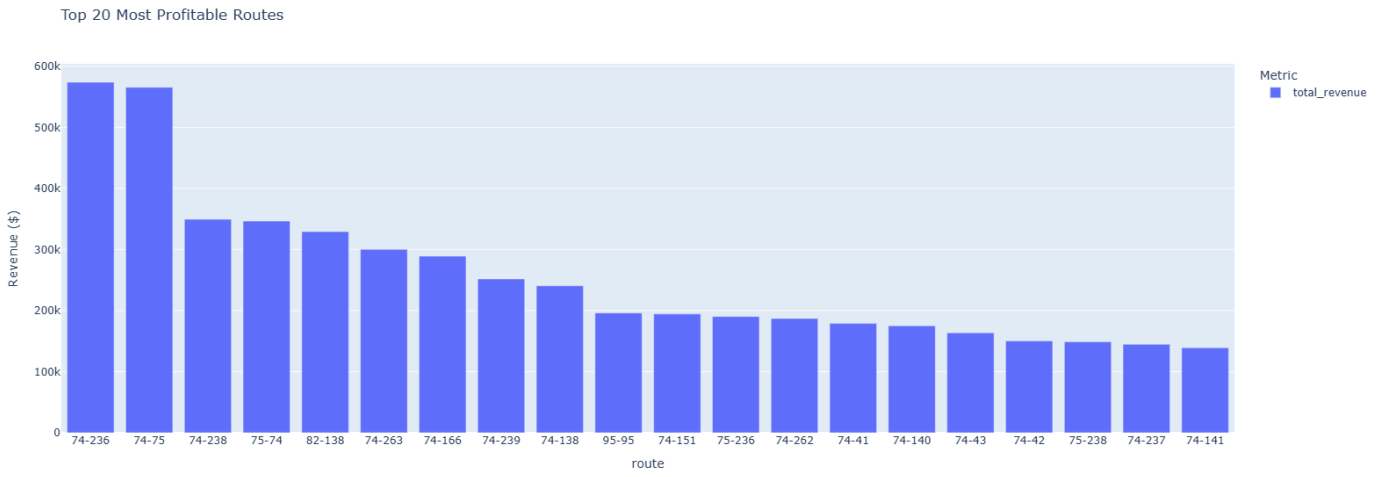


Insight: Credit card payments yield higher tips than cash.

Business Value: Encourages cashless payments to boost driver earnings.

3.2 Route Profitability

Visualisation: Interactive dashboard (Plotly) showing:



Insight:

- Routes to/from airports (location id 74) and business districts are most profitable.
- Some short-distance routes yield high revenue per mile.

Business Value:

- Enables strategic driver positioning.
- Supports route-based pricing models and fleet optimisation.

4. Conclusion

This phase of the project demonstrated the power of Hadoop MapReduce in processing large-scale transportation data. The visualisations provided clear, actionable insights that can help:

- Improve operational efficiency
- Enhance customer satisfaction
- Maximise revenue through data-driven strategies

The combination of distributed processing and effective visualisation bridges the gap between raw data and business intelligence.

References

1. NYC Open Data – TLC Trip Records

2. Dean & Ghemawat (2004) – MapReduce
3. White (2015) – *Hadoop: The Definitive Guide*
4. Apache Hadoop Documentation
5. McKinney (2017) – *Python for Data Analysis*

Appendix

A. GitHub Repository

`https://github.com/mmathapelothotse/bigdata-transport-analysis.git`

B. Video Demonstration

[your-video-platform]
