Big Data Analytics with Scala and Apache Spark

M.Sc. course on "Technologies for Big Data Analysis" - Assignment 3

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1 Introduction

The current document is a technical report for the third programming assignment in the M.Sc. course on *Technologies for Big Data Analysis*, offered by the *DWS M.Sc Program*[1] of the Aristotle University of Thessaloniki, Greece. The course is taught by Professor Apostolos Papadopoulos [2]. The authors attended the course during their first year of Ph.D. studies at the Institution.

The assignment contains 4 sub-problems and is part of a series, comprising 3 programming assignments on the following topics:

Assignment 1 Multi-threading Programming and Inter-Process Communication
Assignment 2 The Map-Reduce Programming Paradigm
Assignment 3 Big Data Analytics with Scala and Apache Spark

In this document we focus on Assignment 3 and its 4 sub-problems. We refer to them as *problems* in the rest of the document for simplicity. The source code of our solution has been made available at the following public repository in the GitHub platform: `https://github.com/Bilpapster/big-data-playground`.

Roadmap. The rest of our work is structured as follows. We devote one section to each one of the 4 problems. That means problems 1, 2, 3 and 4 are presented in section 2, section 3, section 4 and section 5 respectively. For each problem, we first provide the problem statement, as given by the assignment. Next, we thoroughly present the reasoning and/or methodology we have adopted to approach the problem and devise a solution. Wherever applicable, we also provide insights about the source code implementation we have developed. Finally, we conclude our work in section 6. The appendix includes the evaluation results for any issues that necessitated them.

2 Problem 1: Word Length Analytics

We discuss here the first problem of the assignment. The main target of the assignment is to get familiar with a simple task leveraging Apache Spark and Scala programming language. This is a WordCount problem's variation.

2.1 Problem Statement

Implement an **Apache Spark** (Scala) program, a variation of the **word-count** problem, to compute the average length of words that start with a specific letter (a-z). The program should sort the results based on the average length, printing first the letters with higher average length. For example:

k – 8.2
a – 5.6
b – 4.8

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Note that you may opt for preprocessing the input text, e.g., transforming all letters to lowercase or ignoring words that start with a number.

2.2 Proposed approach

2.2.1 Setting. Our implementation is run and tested in a Linux environment with 12 cores, using the Scala programming language version 2.13.15 and Apache Spark version 3.5.3. We have used SBT as the build tool of our solution. We have used the Software Development Kit (JDK) version 11.0.11. The source code is developed in IntelliJ IDEA Community Edition 2021.1.1 and managed using SBT as the build tool. All dependencies of the project can be found in the `build.sbt` file located at the root folder of the project. The project is compiled and executed directly from the IntelliJ IDEA.

To run the project, open the `src/main/scala/Task1WordLength.scala` file in IntelliJ IDEA, and execute the main method. After successful execution of the program, the results can be viewed under the `output/task1` directory.

2.2.2 Implementation. The proposed approach leverages the Apache Spark computing framework to calculate the average word length for each one of the 26 letters in the Latin alphabet. In particular, the input text is read and tokenized into words. As part of a preprocessing step, all letters are transformed to lowercase and all words that start with a number are dropped.

In order to compute the average length for each initial letter, we leverage the `RDD` API of Apache Spark. More specifically, we use a `PairRDD` that stores composite key-value pairs in the form `(letter, (word_length, 1))`. The key of each pair is the initial letter of the respective word (`letter`). The value of each pair is a pair itself, having as (false) key the length of the word (`word_length`) and as (false) value a unary value (1). We use the term *false* for the key and value of the inner pair, since we do not utilize them as an actual key-value pair. As a matter of fact, we treat the inner pair as a plain tuple of values,.

Subsequently, we group all pairs by key (i.e., initial letter) and compute the following two intermediate results *per initial letter*:

(1) sum of word lengths that start with the respective letter, by adding up all false keys of the inner pair, and
(2) total number of words that start with the respective letter, by adding up all unary values (false values) of the inner pair.

Having computed these intermediate results for each initial letter, the average length can be computed as the fraction

$$average\ word\ length_{\ letter} = \frac{sum\ of\ word\ lengths_{\ letter}}{total\ number\ of\ words_{\ letter}},\ \forall letter \in Latin\ Alphabet$$

As a final step, the results are sorted in descending order w.r.t. the average length and saved to a text file. By default, after successful execution of the program, the results can be found under the `output/task1` directory.

2.2.3 Evaluation. The experiments were executed using the dataset `SherlockHolmes.txt`. The results are listed below in a 10-column format and graphically depicted in Figure 1.

c:7.19	p: 7.01	v: 5.98	z: 5.74	k: 5.37	m: 5.14	w: 4.28	y: 3.72	x: 3.41
e: 7.11	r: 6.87	g: 5.93	u: 5.61	l: 5.34	n: 4.81	h: 3.81	t: 3.64	o: 3.01
q: 7.01	d: 6.37	s: 5.8	j: 5.59	f: 5.17	b: 4.54	a: 3.74	i: 3.46	

3 Problem 2: Movie Analytics

The second problem focuses on producing analytic insights from an IMDB dataset.

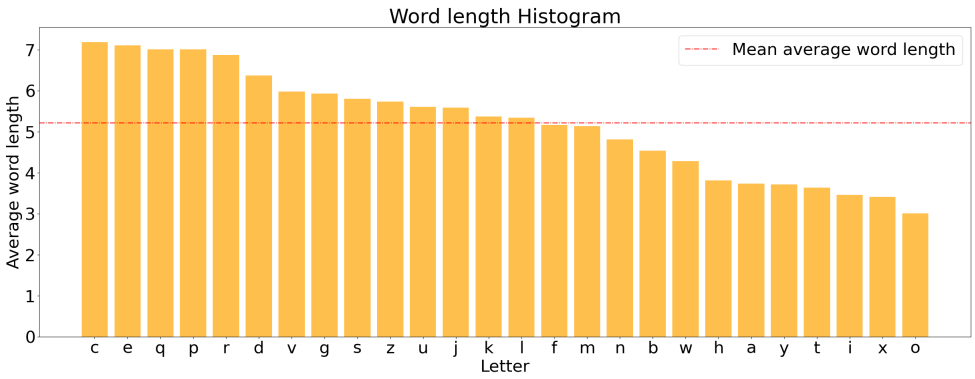


Fig. 1. A histogram depicting the average word length (y-axis) for every letter of the Latin alphabet (x-axis). The mean average length is shown as a horizontal red dashed line.

3.1 Problem Statement

Implement a **MapReduce** program to perform analytics tasks on an IMDB dataset about movies. The utter goal of your analysis would be to extract useful insights from the available movie data that will assist the IMDB team provide better recommendations for movies, based on their genre and/or country. In particular, the dataset (`movies.csv`) contains the following fields:

- imdbID: unique identifier of the movie in the IMDB database
- title: the movie title
- year: the year the movie was first released
- duration: the duration of the movie
- genre(s): the genre or genres in which the movie is classified
- premier date: the date of the first showing of the movie
- score: the IMDB score of the movie
- country/-ies: the country or countries the movie was produced in

You are asked to implement Map-Reduce source code in Java programming language for the following analytics tasks:

- Calculate the total duration of all movies per country. Note that in case multiple countries are recorded for a movie, the respective duration should be counted for all of them separately.
- Calculate the total number of movies per year and genre, having IMDB score over 8. For movies that have more than one genre, the sum should be separate for each genre.

3.2 Proposed approach

3.2.1 Setting. Our implementation is run and tested in a Linux environment with 12 cores, using the Java programming language. We have used the Java Development Kit (JDK) version 11.0.11. The source code is developed in IntelliJ IDEA Community Edition 2021.1.1 and managed using Maven as the build tool.

The project's dependencies, including Hadoop libraries, are defined in the `pom.xml` file located in the root of the repository. The project is compiled and executed directly from IntelliJ IDEA.

To run the project, open the `MovieAnalyticsMaster` class in IntelliJ IDEA, and execute the main method. You will need to specify the following command-line arguments:

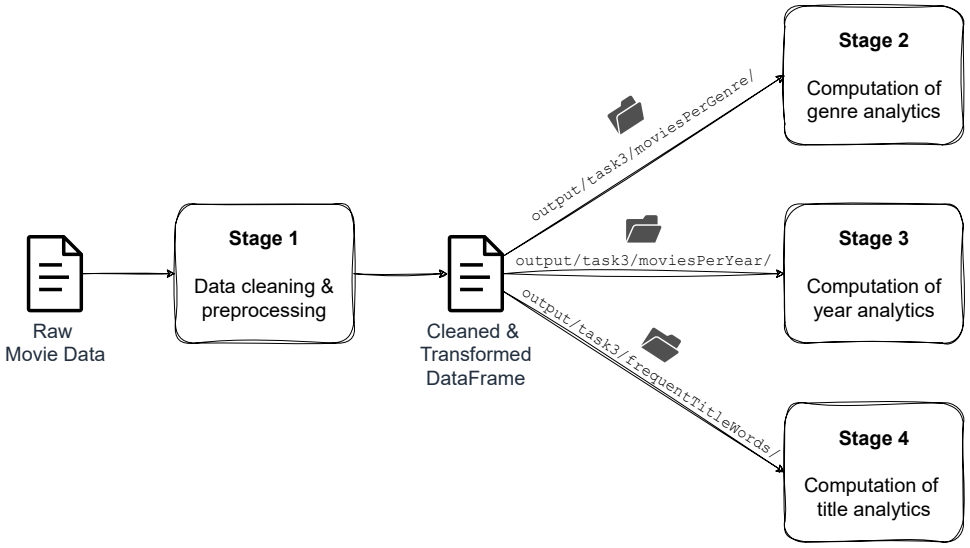


Fig. 2. The MapReduce solution architecture for the movie analytics problem. Two separate jobs are executed to solve the two tasks, namely duration per country (green) and movies per year & genre (yellow). The two tasks also create separate subdirectories for writing the results.

- <input_path> specifies the directory containing the input text files, located at `map-reduce/movieAnalytics/input`.
- <output_path> specifies the directory where the MapReduce output will be written, which will be created in the `out` folder.

IntelliJ IDEA will handle the compilation and execution automatically when the main method is run. Make sure to configure the input and output paths as required for your specific run. Note that the command-line arguments must follow the specified order and format. If any of the arguments are missing or invalid, the program will terminate with an appropriate error message.

3.2.2 Implementation. The proposed approach leverages the MapReduce programming paradigm to compute the analytical insights for the two tasks. Figure 3 depicts the architecture of our solution as a diagram. We opt for executing two separate jobs; one for each task presented by the problem statement.

Task 1: Duration per country. One map-reduce cycle is enough to handle this task, as depicted in the top part of Figure 3 in green color. The map function parses the CSV file line by line and extracts the useful fields from each line. In this case, the useful fields are the country (or countries) the movie was produced and the movie duration, i.e., the fourth and ninth fields in the input line respectively. We employ more complex logic to handle cases where there are multiple countries in a single movie. In particular, we parse again the field and tokenize it into the separate countries, producing a key-value pair for each country-duration pair within a movie. The reduce function is, then, trivial; it just adds up the durations (value) per country (key) and outputs the results. The interested reader can refer to the `CSVProcessor.java` (mapper), `AnayticsEngine.java` (reducer) and `MovieAnalyticsMaster.java` (driver) files for the source code implementation of our solution.

Task 2: Movies per year & genre w.r.t. score constraint. The task is similar to the first one, with the only difference lying in the fields extracted from the input CSV line. In this case, we are interested about the year, the genre (or

genres) and score fields, i.e., the third, fifth and seventh fields in the input CSV line. The map function produces key-value pairs in the form `(composite_key, 1)`, where the composite key consists of the year and the genre of the respective movie concatenated by an underscore, e.g., `2024_action`. We handle multiple genres per movie similarly with the multiple countries in task 1. We employ the same trivial reducer that adds up the values (ones) per (composite) key, as shown in the bottom part of Figure 3 in yellow color.

3.2.3 Evaluation. Our solution is tested using the provided IMDB dataset, namely `movies.csv`. We list the execution results in Appendix A.

4 Problem 3: Movie Analytics

The third problem focuses on producing analytic insights into a movies dataset.

4.1 Problem Statement

In this problem, you are provided with a dataset that contains information about movies. Each record represents a movie and includes three main columns (attributes), namely `movieId`, `title` and `genres`. An example record of the dataset is the following:

```
1,Toy Story (1995),Adventure|Animation|Children|Comedy|Fantasy
```

Note that a movie can belong to multiple genres (e.g., adventure, fantasy, and so on). The genres are separated by a vertical line ('|') in the respective field. Your Apache Spark (Scala) application should compute the following analytics:

(1) **How many movies are there for each genre?** If a movie belongs to multiple genres, it should be counted to all these genres. Sort the results by the name of genre in alphabetical order.
(2) **How many movies have been filmed per year?** Note that the year a movie was filmed is currently encoded into a composite movie title, e.g., "`Toy Story (1995)`". Show the top 10 years with the most movies filmed within them.
(3) **Which are the words that appear at least 10 times in the titles of the movies, and what is their total frequency?** You can ignore words that have less than 4 characters. Sort the results, showing first the words with the higher frequency.

4.2 Proposed approach

4.2.1 Setting. Our implementation is run and tested in a Linux environment with 12 cores, using the Scala programming language version 2.13.15 and Apache Spark version 3.5.3. We have used SBT as the build tool of our solution. We have used the Software Development Kit (JDK) version 11.0.11. The source code is developed in IntelliJ IDEA Community Edition 2021.1.1 and managed using SBT as the build tool. All dependencies of the project can be found in the `build.sbt` file located at the root folder of the project. The project is compiled and executed directly from the IntelliJ IDEA.

To run the project, open the `src/main/scala/Task3MovieAnalytics.scala` file in IntelliJ IDEA, and execute the main method. After successful execution of the program, the results can be viewed under the `output/task3` directory.

4.2.2 Implementation. We leverage Apache Spark *DataFrames* API to calculate the aforementioned analytical queries. Our proposed approach comprises the following four stages:

Stage 1: Data cleaning and preprocessing
Stage 2: Computation of genre analytics (query 1)
Stage 3: Computation of year analytics (query 2)
Stage 4: Computation of title analytics (query 3)

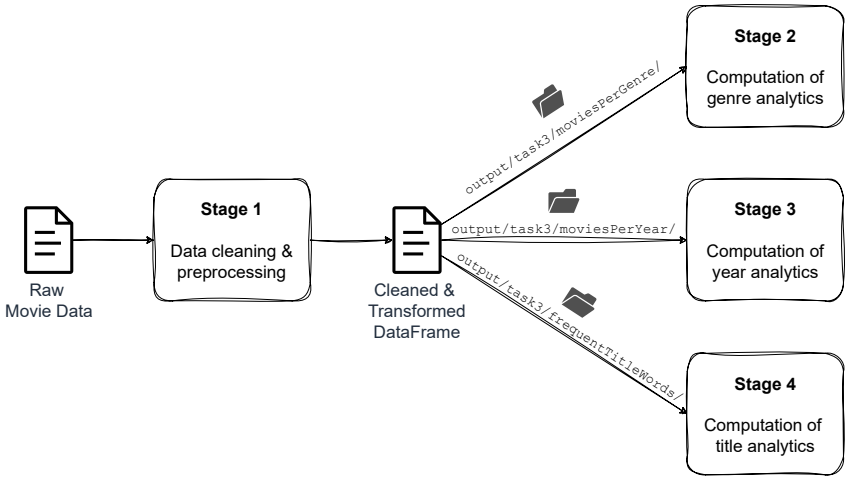


Fig. 3. The MapReduce solution architecture for the movie analytics problem. Two separate jobs are executed to solve the two tasks, namely duration per country (green) and movies per year & genre (yellow). The two tasks also create separate subdirectories for writing the results.

Figure 3 graphically depicts the four stages, as well as their assembly in a workflow. We elaborate on each stage separately in the rest of the Subsection.

Stage1: Data Cleaning and preprocessing. In this stage, we address data quality issues that are present in the raw movie data. Missing production year, missing genres and trailing whitespaces in the title string are the detected data quality issues. To address these issues, we explicitly mark the movie year as "N/A" (not available) & movie genre as "(no genre listed)" and trim the composite title strings, respectively. Subsequently, we transform the data representation to a more efficient form, by extracting the actual title and year to separate fields (instead of a composite one) and splitting the genres composite string field to an array of genres. Throughout the whole process, we **use solely the DataFrame API** of Apache Spark, leveraging also the pattern matching functionality of Scala. A small sample of the cleaned and transformed DataFrame shown in Figure 3 is depicted below:

```
+-------+--------------------+--------------------+----+
|movieId|               title|              genres|year|
+-------+--------------------+--------------------+----+
|      1|           Toy Story|[Adventure, Anima...|1995|
|      2|             Jumanji|[Adventure, Child...|1995|
|      3|    Grumpier Old Men|   [Comedy, Romance]|1995|
|      4|   Waiting to Exhale|[Comedy, Drama, R...|1995|
|      5|Father of the Bri...|            [Comedy]|1995|
+-------+--------------------+--------------------+----+
```

Stage 2: Computation of genre analytics. In this stage, we use the cleaned and transformed data to compute analytical insights into the movie genres. In particular, we use the DataFrame API (`select()`, `group_by()`, etc.) to calculate the number of movies that belong to each genre. An implementation detail of our solution lies in handling the cases where a movie belongs to multiple genres. To ensure the integrity of the computed analytics, we opt for using the `explode()` function of the DataFrame API, to transform the array of genres to separate

genre items. The analytics are, then, computed on top of this extra transformation, enabling us to include **a movie into the calculations of all the genres it belongs**.

Stage 3: Computation of year analytics. In this stage, we use the cleaned and transformed data to compute analytical insights into the movie production years. Similarly to Stage 2, we leverage exclusively the DataFrame API to calculate the total number of movies filmed each year. In this case, the `group_by` operation is more straightforward, since the cleaned and transformed DataFrame contains a dedicated column for the movie production year.

Stage 4: Computation of title analytics. Similarly to Stage 2, we use operations available from the DataFrame API to calculate the most frequently used words in the movie titles. We, leverage the `split(" ")` and `explode()` functions to transform titles, first, into an array of words and, then, into separate words that are finally grouped and aggregated. We remove words that have less than 4 characters and fundamental stopwords, such as "with", or "from", in order to obtain analytical insights of high quality.

4.2.3 Evaluation. Our solution is tested using the raw movie data, namely `movies.csv`. We list the execution results in Appendix B.

Stage 2: Computation of genre analytics. We list here the execution results for the genre analytics query in a 6-column format.

Action: 7348	Comedy: 16870	Drama: 25606	IMAX: 195	Sci-Fi: 3595	Western: 1399
Adventure: 4145	Crime: 5319	Fantasy: 2731	Musical: 1054	Thriller: 8654	N/A: 5062
Animation: 2929	Documentary:	Film-Noir: 353	Mystery: 2925	War: 1874	
Children: 2935	5605	Horror: 5989	Romance: 7719		

Stage 3: Computation of year analytics. We list here the execution results for the year analytics query in a 3-column format, i.e., the top 10 years with the most movies. We observe that these years span the time period between 2009 and 2018, excluding 2015, indicating a heavy film production process in this decade. Figure 4 depicts the distribution of movies per year for all years in chronological order. Our findings indicate a clear long-tail distribution of movies over the years, with a burst of new movies over the last decade.

2015: 2512 movies	2013: 2173 movies	2009: 1724 movies
2016: 2488 movies	2018: 2032 movies	2010: 1691 movies
2014: 2406 movies	2012: 1978 movies	
2017: 2373 movies	2011: 1838 movies	

Stage 4: Computation of title analytics. We list in Appendix B the execution results for the title analytics query.Also, Figure 5 depicts a word cloud with the most frequently used words in movie titles, found in the dataset used for evaluating our solution. Note that the bigger a word is, the more frequently it appears in movie titles.

5 Problem 4: Probabilistic graph

We discuss here the fourth problem of the assignment. The main target of the assignment is to get acquainted with performing various MapReduce phases on a pipeline frame.

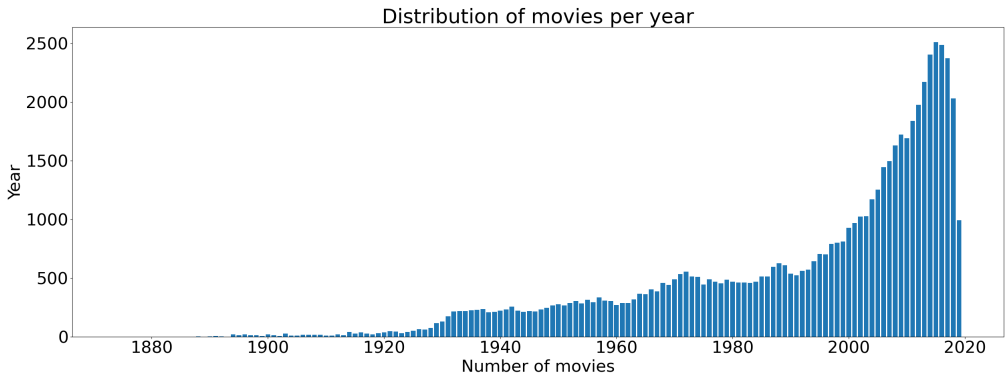


Fig. 4. The distribution of the total number of movies per year in the dataset used for evaluating our solution.

Fig. 5. A word cloud depicting the most frequent words appearing in the titles of the movies in the dataset examined. The bigger a word is, the more frequently it appears in the titles of the movies.

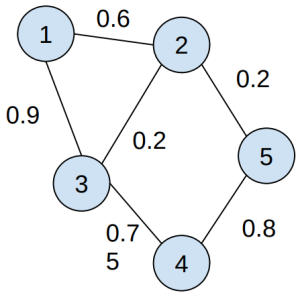
5.1 Problem Statement

We are given an input file in text format where each line contains a connection between two vertices of a network and a probability value. For each edge e, there is a probability value $p(e)$ which indicates the probability that the two vertices are connected by the edge. Obviously, the values of $p(e)$ range between 0 and 1. The values in each line are separated by a space. Consider the network shown in the previous figure. The edge connecting vertices 4 and 5 has a probability of 0.8, the edge connecting vertices 2 and 3 has a probability of 0.2, etc.

The file corresponding to this graph would be:

1 2 0.6, 1 3 0.9, 2 3 0.2, 3 4 0.75, 2 5 0.2, 4 5 0.8,

The edges are generally stored in random order in the file, so we cannot assume they have a specific arrangement.



The following tasks are requested:

(1) Write a Java program that computes the average degree for all the vertices.
(2) The average degree is defined as the sum of the probabilities of the edges that fall on a vertex.
(3) For example, in the previous diagram, the average degree of vertex 3 is $0.9 + 0.2 + 0.75 = 1.85$.
(4) Before performing this calculation, you should ignore all edges with a probability less than a threshold T , which should be passed as a parameter to the main function.
(5) Modify the code from task 1 so that, at the end, only the vertices with an average degree greater than the average of the degrees of all the vertices are displayed in the output.

5.2 Proposed approach

5.2.1 Setting. Our implementation is run and tested in a Linux environment with 12 cores, using the Java programming language. We have used the Java Development Kit (JDK) version 11.0.11. The source code is developed in IntelliJ IDEA Community Edition 2021.1.1 and managed using Maven as the build tool.

The project's dependencies, including Hadoop libraries, are defined in the `pom.xml` file located in the root of the repository. The project is compiled and executed directly from IntelliJ IDEA.

To run the project, open the `GraphMaster` class in IntelliJ IDEA, and execute the main method. You will need to specify the following command-line arguments:

- `<input_path>` specifies the directory containing the input text files, located at `map-reduce/ probabilisticGraph /input`.
- `<output_path>` specifies the directory where the MapReduce output will be written, which will be created in the `out` folder.
- `<T>` is the minimum edge-degree threshold for vertices to be included in the results.

IntelliJ IDEA will handle the compilation and execution automatically when the main method is run. Make sure to configure the input and output paths as required for your specific run.

Note that the command-line arguments must follow the specified order and format. If any of the arguments are missing or invalid, the program will terminate with an appropriate error message.

5.2.2 Implementation. The problem at hand involves processing a probabilistic graph, where each edge connects two vertices with a probability value. The task is to compute the average degree for each vertex, considering only edges whose probability exceeds a given threshold T. The methodology proposed here utilizes a distributed MapReduce framework, implemented using Hadoop, to efficiently process and analyze large-scale graph data. The approach is divided into three main phases, each handled by separate MapReduce jobs, with intermediate results passed between the phases.

The `GraphMaster` class serves as the orchestrator of the entire MapReduce process. It manages the execution of the three phases, invoking the appropriate MapReduce jobs in sequence. The main steps executed by `GraphMaster` are:

(1) It retrieves the command-line arguments, including the input and output directories as well as the threshold value T, which determines which edges to consider in the graph.
(2) It initiates the first MapReduce job to compute the degree of each vertex in the graph. The input consists of edge data, and the output is a summation of edge probabilities for each vertex.
(3) After the first job completes, the `GraphMaster` starts the second MapReduce job to calculate the mean degree of the graph, using the results from the first job.
(4) Once the mean degree is computed, `GraphMaster` starts the third MapReduce job, which filters out the vertices with degrees lower than the mean degree.
(5) It cleans up intermediate directories after each phase and moves the final output to the desired location.

`GraphMaster` coordinates these steps by configuring and executing the MapReduce jobs, ensuring that each phase depends on the results of the previous one.

The entire process consists of three MapReduce jobs, executed sequentially:

(1) **Phase 1:** The first job computes the degree of each vertex by summing the probabilities of the edges connected to it. It produces intermediate results for each vertex.
(2) **Phase 2:** The second job calculates the mean degree by summing the degrees from the first phase and dividing by the total number of vertices.
(3) **Phase 3:** The third job filters out the vertices with a degree lower than the mean degree and produces the final filtered result.

After each job completes, intermediate data is written to disk and passed as input to the subsequent job. The final output consists of the vertices whose degree exceeds or equals the mean degree.

Phase 1: Calculating Vertex Degree The first MapReduce job is responsible for calculating the degree of each vertex in the graph, where the degree is defined as the sum of the probabilities of the edges connected to that vertex. The degree of each vertex is computed by the `GraphMapper` and `GraphReducer` classes.

The `GraphMapper` class reads each edge from the input data, which consists of lines containing two vertices and the associated probability value. It splits each line into two components (the two vertices), and for each vertex, it emits the corresponding probability value as the output. The mapper also checks if the probability value exceeds the threshold T, which is provided as a configuration parameter. If the probability is greater than or equal to T, it emits the vertex along with the corresponding probability.

The `GraphReducer` class receives the vertex and associated probability values emitted by the mapper. For each vertex, it sums up all the probabilities of the edges connected to that vertex, and emits the pair as output.

Phase 2: Calculating the Mean Degree The second phase of the approach calculates the mean degree of all vertices. This is done by summing the degree values from the previous phase and dividing by the total number of vertices.

The `MeanMapper` class receives the degree values from the output of the first MapReduce job. It emits two key-value pairs for each input line: a count of the number of vertices and the sum of the degree values. These are emitted with fixed keys (`"count"` and `"sum"`) so that they can be aggregated in the reducer.

The `MeanReducer` class processes the count and sum values emitted by the mapper. It calculates the total sum and count of vertices and then writes these values as output. The mean degree is calculated by dividing the sum by the count, and the result is stored for use in the next phase.

Phase 3: Filtering Vertices by Mean Degree In the third phase, the vertices whose degree is greater than or equal to the mean degree calculated in Phase 2 are selected. This phase uses the results from Phase 1 and Phase 2, applying the filtering criteria to retain only those vertices with a degree greater than or equal to the mean.

The `FilterMapper` class takes the degree values emitted by the first reducer and writes them as key-value pairs. Each key is a vertex, and the value is the degree of that vertex. The mapper does not perform any filtering; instead, it simply passes the values along to the reducer.

The `FilterReducer` class filters out the vertices whose degree is less than the mean degree. It retrieves the mean degree from the configuration, and for each vertex, it compares the degree value to the mean. If the degree is greater than or equal to the mean, it emits the vertex along with its degree. This final output contains only the vertices that satisfy the filtering criteria.

5.2.3 Evaluation. The experiments were executed using the dataset ‘collins.txt‘ with a parameter setting of $T = 0.8$.

To provide a comprehensive overview, the results of the experiment, including the detailed values derived from the dataset, are presented in subsection B.1 in a 2-column format.

6 Conclusion

In this document we have presented our solutions and rationale for solving the second assignment of the M.Sc. course on *Technologies for Big Data Analysis*, offered by the *DWS M.Sc. Program*. For each one of the four problems of the assignment, we have presented their statement, as well as the solution approach we have adopted. All execution results with the provided datasets can be found in the appendices of our work.

A Problem 2 execution results

We list here the execution results of our solution for the second problem (movie analytics) tested on the `movies.csv` dataset. Task 1 (duration per country) produces the following results:

Afghanistan: 815
Albania: 646
Algeria: 2115
American Samoa: 247
Angola: 357
Argentina: 28813
Armenia: 264
Aruba: 739
Australia: 66068
Austria: 22925
Bahamas: 560
Bahrain: 87
Bangladesh: 429
Barbados: 92
Belarus: 427
Belgium: 54192
Bermuda: 95
Bhutan: 291
Bolivia: 797
Bosnia and Herzegovina: 2207
Botswana: 295
Brazil: 27333
Bulgaria: 5430
Burkina Faso: 903
Burma: 95
Cambodia: 894
Cameroon: 615
Canada: 210826
Chad: 493
Chile: 6178
China: 42089
Colombia: 3810
Congo: 88
Costa Rica: 431
Croatia: 4340
Cuba: 2899
Cyprus: 948
Czech Republic: 15317
Czechoslovakia: 8434
Cóte d'Ivoire: 180
Denmark: 44186
Dominican Republic: 866
East Germany: 2095
Ecuador: 893
Egypt: 3090
El Salvador: 167
Estonia: 4651
Ethiopia: 537
Faroe Islands: 97
Federal Republic of Yugoslavia: 2167
Finland: 48990
France: 467279
Gabon: 80
Georgia: 1846
Germany: 226808
Ghana: 655
Greece: 20305
Greenland: 90
Grenada: 79
Guatemala: 638
Guinea: 90
Haiti: 498
Honduras: 80
Hong Kong: 66567
Hungary: 19668
Iceland: 7839
India: 110215
Indonesia: 3931
Iran: 11762
Iraq: 1365
Ireland: 26506
Isle Of Man: 396
Israel: 16662
Italy: 288407
Jamaica: 807
Japan: 178558
Jordan: 1313
Kazakhstan: 2145
Kenya: 523
Korea: 90
Kosovo: 188
Kuwait: 273
Kyrgyzstan: 400
Laos: 289
Latvia: 2297
Lebanon: 1289
Liberia: 283
Libya: 520
Liechtenstein: 1011
Lithuania: 3772
Luxembourg: 11976
Macao: 175
Madagascar: 204
Malaysia: 1338
Mali: 220
Malta: 885
Martinique: 103
Mauritania: 515
Mexico: 35560
Micronesia: 85
Moldova: 95
Monaco: 189
Mongolia: 186
Montenegro: 439
Morocco: 4525
Namibia: 105
Nepal: 797
Netherlands: 47054
New Zealand: 14561
Nicaragua: 183
Nigeria: 494
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Norway: 26476
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Panama: 903
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Philippines: 7882
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Portugal: 15232
Puerto Rico: 1322
Qatar: 1036
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Russia: 50757
Rwanda: 527
Samoa: 110
Saudi Arabia: 490
Senegal: 1462
Serbia: 4337
Serbia and Montenegro: 1314
Singapore: 4557
Slovakia: 2525
Slovenia: 2956
Somalia: 90
South Africa: 14688
South Korea: 56245
Soviet Union: 51353
Spain: 116651
Sri Lanka: 318
Suriname: 105
Sweden: 68956
Switzerland: 34516
Syria: 447
Taiwan: 16618
Tajikistan: 351
Tanzania: 441
Thailand: 10189
The Democratic Republic Of Congo: 98
Trinidad and Tobago: 86
Tunisia: 2236
Turkey: 20068
UK: 492616
USA: 2276142
Uganda: 243
Ukraine: 4616

United Arab Emirates: 3202
Uruguay: 2038
Uzbekistan: 324
Vanuatu: 100
Venezuela: 2014
Vietnam: 1261
West Germany: 58480
Yugoslavia: 8742
Zaire: 80
Zimbabwe: 210

Task 2 (movies per year and genre) produces the following results:

1973_Adventure: 1
1973_Drama: 1
1973_History: 1
1976_Comedy: 2
1976_Drama: 1
1976_History: 1
1976_Mystery: 1
1976_Romance: 1
1979_Adventure: 1
1979_Crime: 1
1979_Mystery: 1
1982_Comedy: 1
1982_Drama: 1
1985_Documentary: 1
1985_History: 1
1988_Comedy: 1
1988_Drama: 2
1988_Sci-Fi: 1
1996_Documentary: 1
1996_Music: 1
2001_Documentary: 1
2001_Music: 1
2002_Documentary: 1
2002_Music: 1
2004_Adventure: 1
2004_Documentary: 2
2004_Drama: 1
2004_Music: 1
2004_Romance: 1
2006_Animation: 1
2006_Crime: 1
2006_Drama: 1
2007_Documentary: 1
2007_War: 1
2008_Action: 1
2008_Crime: 1
2008_Drama: 1
2009_Documentary: 1
2015_Action: 1
2015_Adventure: 1
2015_Animation: 1

B Problem 3 execution results

love: 851
night: 519
story: 495
life: 476
last: 451
girl: 387
black: 352
time: 350
little: 335
dead: 327
death: 323
house: 311
world: 306
movie: 286
christmas: 274
blood: 271
dark: 258
city: 250
american: 249
white: 235
your: 225
king: 219
lost: 209
days: 209
secret: 202
that: 201
blue: 200
woman: 197
good: 196
three: 194
wild: 192
summer: 185
great: 181
home: 181
girls: 180
don't: 179
live: 179
lady: 169
island: 168
high: 166
this: 165
road: 159
back: 158
what: 156
kill: 156
street: 155
moon: 154
first: 153
about: 152
the): 147
hell: 146
legend: 146
killer: 145
heart: 145
return: 144
when: 142
like: 142
young: 139
ghost: 138
family: 137
star: 137
women: 135
part: 135
boys: 134
game: 133
murder: 129
land: 129
fire: 125
adventures: 121
people: 121
under: 120
after: 117
evil: 116
down: 114
journey: 114
never: 114
beyond: 113
devil: 112
perfect: 111
living: 111
long: 110
space: 108
monster: 108
wedding: 108
school: 108
best: 108
year: 107
battle: 106
final: 106
baby: 106
come: 106
angel: 105
eyes: 104
happy: 103
before: 102
earth: 101
without: 101
dragon: 101
dream: 101
seven: 100
kiss: 99
room: 99
magic: 99
it's: 98
party: 98
just: 98
town: 98
children: 98
man,: 98
will: 97
four: 97
tale: 97
heaven: 97
other: 95
river: 95
fear: 95
over: 95
they: 94
here: 94
golden: 93
sweet: 93
five: 93
years: 92
beautiful: 92
film: 91
west: 91
case: 91
green: 90
crazy: 88
water: 88
once: 88
fall: 87
song: 87
wolf: 86
paris: 85
deadly: 85
queen: 85
america: 84
miss: 84
true: 84
midnight: 84
into: 83
hero: 83
snow: 82
dance: 81
light: 81
jack: 81
hard: 81
goes: 81
hollywood: 80

only: 79
princess: 79
rock: 79
another: 79
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prince: 78
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john: 77
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terror: 77
cold: 77
shadow: 77
zero: 76
brothers: 76
call: 76
strange: 76
take: 75
inside: 75
money: 74
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charlie: 74
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wife: 73
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gold: 72
mountain: 71
truth: 71
revenge: 71
book: 71
beast: 69
face: 69
lucky: 69
adventure: 69
edge: 69
york: 69
deep: 69
hotel: 68
devil's: 68
vampire: 68
stranger: 68
dawn: 68
child: 68
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dangerous: 67
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born: 67
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blues: 66
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lives: 66
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beach: 65
silent: 65
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times: 65
captain: 65
have: 65
jungle: 65
tomorrow: 64
forever: 64
dirty: 64
detective: 64
away: 64
curse: 64
alien: 64
body: 63
train: 63
double: 63
private: 63
second: 63
alone: 63
darkness: 63
daughter: 62
diary: 62
nothing: 62
point: 62
beauty: 61
spring: 61
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broken: 61
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nightmare: 60
comedy: 60
comes: 59
master: 59
place: 59
naked: 58
super: 58
johnny: 58
made: 58
killing: 58
show: 57
stars: 57
(les: 57
witch: 57
santa: 57
holiday: 57
rose: 57
still: 56
nights: 56
ride: 56
hill: 56
things: 56
flight: 56
upon: 56
fury: 56
rise: 55
rain: 55
garden: 55
club: 55
brother: 55
right: 55
know: 55
doctor: 55
valley: 54
phantom: 54
treasure: 54
machine: 54
zombie: 54
blind: 54
glory: 54
force: 54
horse: 53
power: 53
welcome: 53
castle: 53
head: 53
music: 53
massacre: 52
attack: 52
real: 52
camp: 52
going: 52
fight: 52
kids: 52
shadows: 52
affair: 52
miracle: 51
hunter: 51
flying: 51
soul: 51
small: 51
alive: 51
future: 50
heroes: 50
london: 50
dogs: 50
through: 50
something: 50
vengeance: 50
tiger: 50
operation: 49
more: 49
wars: 49
sunday: 49
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flesh: 49
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gang: 49
secrets: 49
broadway: 49
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walk: 48
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grand: 43
louis: 43
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than: 42
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thing: 42
pink: 42
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justice: 41
frankenstein: 41
kingdom: 40
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heat: 40
anna: 40
fast: 40
kung: 40
late: 40
games: 40
teenage: 40
work: 40
dracula: 40
freedom: 40
vacation: 40
man's: 40
trip: 40
cool: 40
i'll: 39
must: 39
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brave: 39
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giant: 39
shark: 39
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billy: 34
hood: 34
easy: 34
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east: 34
half: 34
weekend: 34
bullet: 34
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blonde: 33
chasing: 33
spirit: 33
amazing: 33
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silver: 33
married: 33
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trial: 32
robin: 32
their: 32
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paul: 32
richard: 32
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lord: 32
carry: 32
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warriors: 30
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mark: 30
color: 30
dancing: 30
tears: 30
danger: 30
county: 30
lonely: 30
elephant: 30
keep: 30
almost: 30
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order: 27
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(zatôichi: 27
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nation: 25
fighting: 25
together: 25
april: 25
madame: 25
taxi: 25
psycho: 25
damned: 25
bell: 25
nobody: 25
scarlet: 25
fatal: 25
cross: 25
cowboy: 25
resurrection: 25
animals: 25
shaolin: 25
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wolves: 25
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2000: 21
frozen: 21
normal: 21
sand: 21
gate: 21
vegas: 21
courage: 21
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moonlight: 21
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purple: 20
die): 20
september: 20
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turn: 20
runner: 20
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lessons: 12
rides: 12
heavenly: 12
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ecstasy: 12
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crocodile: 12
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butcher: 12
range: 12
pete: 12
sick: 12
falk:: 12
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zatoichi: 12
uuno: 12
mail: 12
won't: 12
hundred: 12
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curious: 12
rogue: 12
bugs: 12
twice: 12
sometimes: 12
done: 12
jazz: 12
danny: 12
really: 12
washington: 12
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johan: 12
fell: 12
legion: 12
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pyaar: 12
cargo: 12
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milk: 12
asterix: 12
vita: 12
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chainsaw: 12
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villa: 11
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vincent: 11
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billion: 11
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stray: 11
lincoln: 11
ivan: 11
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kick: 11
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brides: 11
dean: 11
help: 11
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died: 11
fruit: 11
dead:: 11
emma: 11
olsen: 11
thomas: 11
viking: 11
fugitive: 11
twins: 11
notte: 11
remains: 11
buddha: 11
samson: 11
swim: 11
feeling: 11
notorious: 11
riders: 11
gospel: 11
vendetta: 11
universal: 11
restless: 11

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juliet: 11
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england: 11
commando: 11
santo: 11
jesse: 11
roger: 11
slaves: 11
gates: 11
waltz: 11
manhunt: 11
beer: 11
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boogie: 10
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cane: 10
emanuelle: 10
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evil:: 10
deadline: 10
runaway: 10
boston: 10
batman:: 10
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shelter: 10
cannibals: 10
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turhapuro: 10
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nazi: 10
dumb: 10
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i've: 10
venice: 10
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senior: 10
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jump: 10
hansel: 10
anniversary: 10
sorry: 10
stupid: 10
juan: 10
drummond: 10
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pony: 10
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jean: 10
election: 10
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germany: 10
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harold: 10
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cemetery: 10
voodoo: 10
union: 10
pants: 10
suspicion: 10
minute: 10
thoughts: 10
piano: 10
daniel: 10

B.1 Problem 4 execution results

In the following 4-columned pages, the experimental results of section's 5 problem are presented, as the raw output of the 3rd MapReduce phase execution.

102: 20.772281
104: 29.609879
105: 27.598046999999998
107: 14.800885000000003
109: 27.163701999999994
110: 16.304225
111: 42.771938
112: 9.670065000000001
113: 28.587929000000003
114: 17.573652999999997
115: 33.936378
116: 25.765458000000002

117: 30.000875
1180: 9.566474
1181: 8.554887
1182: 10.499468
1183: 8.272158999999998
1186: 8.551493
120: 8.667856
121: 24.678666000000003
122: 62.881582
124: 23.14891
128: 13.860000000000001
129: 13.828262
130: 12.778032
131: 14.548629
132: 13.780112000000003
133: 12.777426
134: 17.525341
135: 12.858882000000001
136: 13.721149
137: 13.660803000000001
138: 13.738254000000001
140: 11.448863
141: 12.826131
143: 12.803862
154: 13.723290000000002
170: 35.83375399999999
174: 39.935224000000005
175: 42.11639699999999
176: 33.780936999999994
180: 9.111828999999998
187: 10.061923
191: 21.271617
192: 22.415023999999995
193: 24.815881999999995
194: 15.367017
197: 19.721797
198: 20.10406
200: 26.785185
202: 20.554610999999998
203: 26.437709999999992
204: 21.193861000000002
205: 18.054205999999997
206: 12.843962
208: 18.285626
209: 9.478037
210: 18.463774999999995
211: 26.206232
213: 8.21817
214: 19.809753000000004
215: 22.834134999999996
216: 22.450407999999996
217: 12.86093
219: 13.857943
220: 26.279680999999997
221: 15.366022000000003
222: 10.174368
223: 31.783763000000004
226: 11.464125999999998
227: 9.910114
228: 26.034533
229: 17.984762
23: 8.068862
231: 11.600534
232: 21.044421999999994
24: 15.912360000000001
244: 20.739924000000002
245: 26.42594699999999
246: 12.422665
247: 12.198811000000001
249: 19.911965999999996
25: 9.950251999999999
250: 20.231632999999995
251: 35.69873999999999
252: 13.855876000000002
254: 8.187458
255: 27.296618
257: 20.167998999999995
258: 13.343784000000001
260: 33.483572999999986
261: 32.508742999999996
264: 12.784288
265: 17.312394
266: 16.947997
267: 26.82996199999999
268: 13.143828000000001
269: 9.54012
27: 18.650638999999998
270: 12.200784000000002
272: 27.8627
273: 20.449326000000003
274: 21.781969000000004
275: 18.921694000000002
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295: 33.319982999999986
296: 26.437148
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320: 15.995923000000003
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324: 14.145467000000002
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326: 9.210550999999999
327: 8.77006
328: 11.502478
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331: 12.199909
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334: 16.773555
335: 12.816709
336: 9.472820000000002
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355: 13.838998000000002
356: 13.709090000000002
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