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INTRODUCTION TO BIG DATA ANALYSIS

Lab instructors

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Lab 04: Spark Streaming

1. Statements

In this Lab, you and your team is going to implement a pipeline of Extract-Transform-Load that perform streamed analysis on time-series data of cryptocurrencies' prices, in particular the price of symbol BTCUSDT from Binance trading platform. Similar to the Lab 1, this lab is also explorative of the frameworks for processing big data, thus you may encounter many unseen issues during the setup as well as the processing steps. You are recommended to provide detailed description of these issues and how to solve them in your report.

Disclaimer:

This exercise is for educational and technical demonstration purposes only. It is hereby declared that no encouragement, endorsement, or recommendation for engaging in cryptocurrency trading, investment, or speculative activities is provided.

1.1. Extract

In the extract stage, you will utilize Binance's APIs to crawl the time-series data about the symbol using **any** programming language that is capable of doing the task, meaning that you are NOT restricted to Python or Scala for this stage. This data is then published through Kafka to the transform stage.

Requirements: Implement a Kafka producer that

- Fetches the price of the symbol from Binance API which contains a floating-point value representing the symbol's price.
- Upon receiving a response from the API, checks if the received JSON conforms the following output format, based on the documentation of Binance:

```
{
  "symbol": <a string>,
  "price": <a floating-point value>
}
```
- Inserts event-time information:
 - Add another field to the above JSON that denotes the timestamp associated with this response, in other words, this is the timestamp that your crawler received this JSON response.

- Refer to *ISO8601 standards* for detailed format of the timestamp, you are recommended to use your language's time-related libraries for processing these timestamps.
- Runs with a frequency of at least once per 100 milliseconds.
- Push those records to a topic in Kafka named **btc-price**.
- You and your team should take screenshots of significant steps that you and the team did, then put them into your report with detailed explanation.

Binance API:

- Reference: <https://developers.binance.com/docs/binance-spot-api-docs/rest-api/market-data-endpoints>
- API: api.binance.com/api/v3/ticker/price?symbol=BTCUSDT

1.2. Transform

The transform stage has two steps that involves Kafka publications and subscriptions. Specifically, the first step requires the calculation of moving average and moving standard deviation within specified sliding windows while the second one computes the Z-scores of latest price against those windows' moving average and standard deviation.

Allowed programming language(s): *Java*, *Python*, and *Scala*. NOTE: your implementations should handle late data with a tolerance of up to **10 seconds** late time.

Requirements:

- Implement a program using Spark Structure Streaming, also including Spark SQL, to:
 - Subscribe to the **btc-price** topic from Kafka of the extract stage.
 - Use event-time processing to group the listened messages into sliding windows of the following lengths: *30s* (30 seconds), *1m* (1 minute or 60 seconds), *5m* (5 minutes), *15m* (15 minutes), *30m* (30 minutes), and *1h* (1 hour or 60 minutes).
 - Compute the moving averages and moving standard deviations by calculating average and standard deviation of prices per window.
 - You should also handle edge cases with your own rules and definitions, then output the results in the following format:

```
{
  "timestamp": <ISO8601 UTC timestamp>,
  "symbol": <a string>,
  [
```

```

    {
      "window": <a string among 30s, 1m, 5m, 15m, 30m, 1h>,
      "avg_price": <a floating-point value>,
      "std_price": <a floating-point value>
    },
    ... # Repeat until avg and std of all windows are provided
  ]
}

```

- Publish the results to another Kafka topic called **btc-price-moving** with append mode.
- Implement a program using Spark Structure Streaming, also including Spark SQL, to:
 - Listen to both of the following Kafka topics: **btc-price** and **btc-price-moving**.
 - With one record read from **btc-price** and another one from **btc-price-moving** that share the same timestamp information, computes the Z-score of the price with respect to each sliding window given in the moving statistics record's information.
 - After handling the edge cases (if any, with your own rules and definitions), output the results in the following format:


```

{
  "timestamp": <ISO8601 UTC timestamp>,
  "symbol": <a string>,
  [
    {
      "window": <a string among 30s, 1m, 5m, 15m, 30m, 1h>,
      "zscore_price": <a floating-point value>
    },
    ... # Repeat until Z-scores of all windows are provided
  ]
}
          
```
 - Publish this result to a new Kafka topic called **btc-price-zscore** by append mode similar to prior tasks.
- You and your team should take screenshots of significant steps that you and the team did, then put them into your report with detailed explanation.

References:

- Z-score: also known as *standard score*, refer to [Standard score - Wikipedia](#) for more details.

1.3. Load

In the load stage, you and your team will use Spark Structured Stream and MongoDB Spark Connector to store the calculated data as a collection under the streaming mode.

Allowed programming language(s): *Java*, *Python*, and *Scala*. NOTE: your implementations should handle late data with a tolerance of up to **10 seconds** late time.

Requirements:

- Setup a MongoDB for persistently storing the computed data, you are free to choose where to install the database management system as well as the method of installation.
- Subscribe to the **btc-price-zscore** Kafka topic from the transform stage and create a Spark Structured Stream from it.
- Write this stream to MongoDB collections named **btc-price-zscore-`<window>`** where **`<window>`** encodes the interval associated with the sliding window (*30s*, *1m*, *5m*, *15m*, *30m*, *1h*). You are free to define the schema of these collections but be sure to denote it in the final report.
- You and your team should take screenshots of significant steps that you and the team did, then put them into your report with detailed explanation.

References:

- MongoDB Documentation: <https://www.mongodb.com/docs/manual/introduction/>

1.4. Bonus

This is a bonus section to the transform stage where shortest windows of negative outcome is found for each price record published in the Kafka topic **btc-price**. There would be 2 such windows: one for the lower prices and another for the higher ones.

Allowed programming language(s): *Java*, *Python*, and *Scala*. NOTE: your implementations should handle late data with a tolerance of up to **10 seconds** late time.

Requirements:

- Implement a program using Spark Structure Streaming, also including Spark SQL, to:
 - Listen to the Kafka topic **btc-price** published in the extract stage.
 - For each price record p received from that topic with an event-time timestamp t , you will need to find at most two records in the 20-second interval after it, .i.e

$(t, t + 20]$, where one is the first encountered message with price higher than that of p and the other is the first with price lower than that.

- Calculate the time difference between each of the found records with t , in floating-point seconds, then publish the results to Kafka topics of **btc-price-higher** and **btc-price-lower**, respectively. For the case where no window of higher (or lower) price is found within this 20-second interval, the program must publish a placeholder record filling the field of length with 20.0.
- The published JSON should have the following format:

```
{
  "timestamp": <ISO8601 UTC timestamp>,
  "<higher/lower>_window": <a floating-point value>
}
```
- The Kafka topics' publications are in append mode.
- You and your team should take screenshots of significant steps that you and the team did, then put them into your report with detailed explanation.

Hint: You may need to employ some form of stateful operations for this part of the lab.

2. Submission Guideline

This lab requires a group's submission where the work of your group's members is compressed into a single file and only one representative may submit this file on Moodle. The submission file contains a single folder named *<GroupID>* where student ID of the first member (that your group has registered in earlier form) is used. Its internal structure will be as follow:

```
<GroupID>
├── docs
│   └── Report.pdf
├── src
│   ├── Extract
│   │   ├── <GroupID>.{py, ipynb, jar, sc, scala}      # Executable files
│   │   └── code                                     # Original code & results for the transform stage, if any
│   ├── Transform
│   │   ├── <GroupID>_moving.{py, ipynb, jar, sc, scala} # Executable files for moving statistics
│   │   ├── <GroupID>_zscore.{py, ipynb, jar, sc, scala} # Executable files for Z-scores
│   │   └── code                                     # Original code & results for the transform stage, if any
└── Load
```

```

├── <GroupID>.{py, ipynb, jar, sc, scala}      # Executable files
├── code                                       # Original code & results for the transform stage, if any
├── Bonus
├── <GroupID>.{py, ipynb, jar, sc, scala}      # Executable files for bonus part
├── code                                       # Original code & results for the bonus part, if any
└── README.md                                # (Optional) Instructions to run your code

```

You must strictly follow the above file structure and compress the whole folder into a ZIP file named *<GroupID>.zip*, which is your final file to be submitted to Moodle.

Grading Criteria

The grading criteria are summarized in the below table.

Requirements	Points
Extract	2
- The crawler get the pricing data without any error.	1
- The timestamp is inserted appropriately.	0.5
- The Kafka producer publishes this data at correct topic.	0.5
Transform	4.25
- The sliding windows are created according to the required intervals.	1
- The means and standard deviations are correctly computed.	1
- These statistics data are parsed into the required formats.	0.25
- The moving statistics are piped to the correct Kafka topic.	0.25
- The price record is matched against statistics of the same event-time.	1
- Z-scores of the matched price are successfully calculated and formatted.	0.5
- The results are directed towards the output topic.	0.25
Load	2
- The MongoDB is setup and running.	1
- The stream is read and written to the appropriate collections in MongoDB.	1
Bonus	1
- Correctly compute the required windows' lengths.	0.75
- Format and publish the results appropriately.	0.25
Report	1.75
- Overview: source code's structure, components, and implemented methods.	0.75
- Detailed explanation: verbal and/or visual illustration of the methods.	0.75
- Contribution table: assigned tasks for each member in the group.	0.25
TOTAL	11

Also note that:

- Ensure your code is well-documented with clear comments.

- Include all necessary files, logs, and screenshots to verify successful execution.
- Each task can be accomplished under complex environments and different programming languages, remember to provide instructions for running each task if this is the case.

Happy Coding and Best of Luck!

The Instructor./.