STAT 694

DATABASE MANAGEMENT FOR DATA SCIENCE

Instructor: Dr. Ajita John

Twitter Search App

TEAM 6

Final Project

GitHub Repository `https://https://github.com/d-manishag/Twitter-Search-App.git`

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Contents

1 Introduction

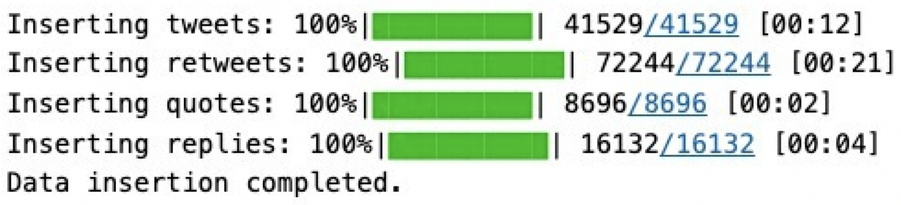
The present work is motivated by acknowledging that various database architectures handling volumes of data integrated to design search applications have great functionality. The work focuses on building a Twitter Search Application on the Twitter data. At the outset, the data is processed, and databases are designed for efficient data storage. The databases are consolidated with relevant interface design to develop a search application resembling Twitter.

2 Dataset

For designing the current application, data encoded using Java Script Object Notation, provided by Twitter, is used. The structure of the data for a tweet in the provided dataset is a dictionary containing various keys such as 'id', 'text', 'created_at', 'source', 'retweet_count', 'favorite_count', 'lang', 'reply_count', 'user_id', and 'hashtags'. Additional keys may be added for retweets, quotes, extended_tweet and replies. The summary of the tweets is as follows.

Objects	Count
Users	117795
Tweets	41529
Re-Tweets	72244
Quoted Tweets	8696
Replies	16132
Total No. of JSON objects	120434

Table 1: Summary Table of the Corona Tweets



```
Inserting tweets: 100%|██████████| 41529/41529 [00:12]
Inserting retweets: 100%|██████████| 72244/72244 [00:21]
Inserting quotes: 100%|██████████| 8696/8696 [00:02]
Inserting replies: 100%|██████████| 16132/16132 [00:04]
Data insertion completed.
```

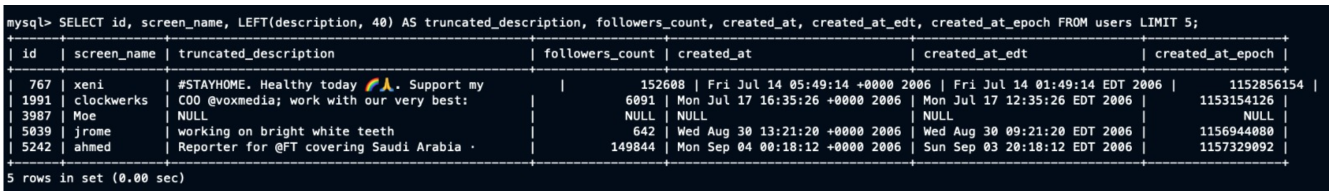
Figure 1: Data Processing in Python

3 Data Model and Data Stores

Database design is an essential aspect of database management. The Twitter JSON document has a complex data structure, and our work implements a hybrid database system for easy access and retrieval of tweets and users. The information in a tweet is stored using MongoDB, a NoSQL database, and MySQL is used to store users' data. MySQL and MongoDB are installed in our systems. Python code is developed to interact with MongoDB and MySQL. The code uses the 'pymongo' library to interact with MongoDB and the 'mysql-connector-python' library to interact with MySQL.

3.1 Relational Database

The user-specific data from the JSON is retrieved, i.e., the user object in tweets with key-value pairs. User data is procured with user-id, username, user description, number of followers, and the date the account was created. This user data is encoded into new JSON, then retrieved for insertion into the table 'user_table' in the user database created in MySQL. MySQL database is designed to store the users not only from the tweets JSON objects but also from the retweeted_status, quoted_status, and in_reply_to_user resulting in a total of 117,795 unique users.



```
mysql> SELECT id, screen_name, LEFT(description, 40) AS truncated_description, followers_count, created_at, created_at_edt, created_at_epoch FROM users LIMIT 5;
+------+-------------+------------------------------------------+-----------------+--------------------------------+---------------------------+------------------+
| id   | screen_name | truncated_description                    | followers_count | created_at                     | created_at_edt            | created_at_epoch |
+------+-------------+------------------------------------------+-----------------+--------------------------------+---------------------------+------------------+
|  767 | xeni        | #STAYHOME. Healthy today 🌈🙏. Support my        |          152608 | Fri Jul 14 05:49:14 +0000 2006 | Fri Jul 14 01:49:14 EDT 2006 |       1152856154 |
| 1991 | clockwerks  | COO @voxmedia; work with our very best:  |            6091 | Mon Jul 17 16:35:26 +0000 2006 | Mon Jul 17 12:35:26 EDT 2006 |       1153154126 |
| 3987 | Moe         | NULL                                     |            NULL | NULL                           | NULL                      |             NULL |
| 5039 | jrome       | working on bright white teeth            |             642 | Wed Aug 30 13:21:20 +0000 2006 | Wed Aug 30 09:21:20 EDT 2006 |       1156944080 |
| 5242 | ahmed       | Reporter for @FT covering Saudi Arabia · |          149844 | Mon Sep 04 00:18:12 +0000 2006 | Sun Sep 03 20:18:12 EDT 2006 |       1157329092 |
+------+-------------+------------------------------------------+-----------------+--------------------------------+---------------------------+------------------+
5 rows in set (0.00 sec)
```

Figure 2: MySQL server - Relational Database with users' table

3.2 Non Relational Database

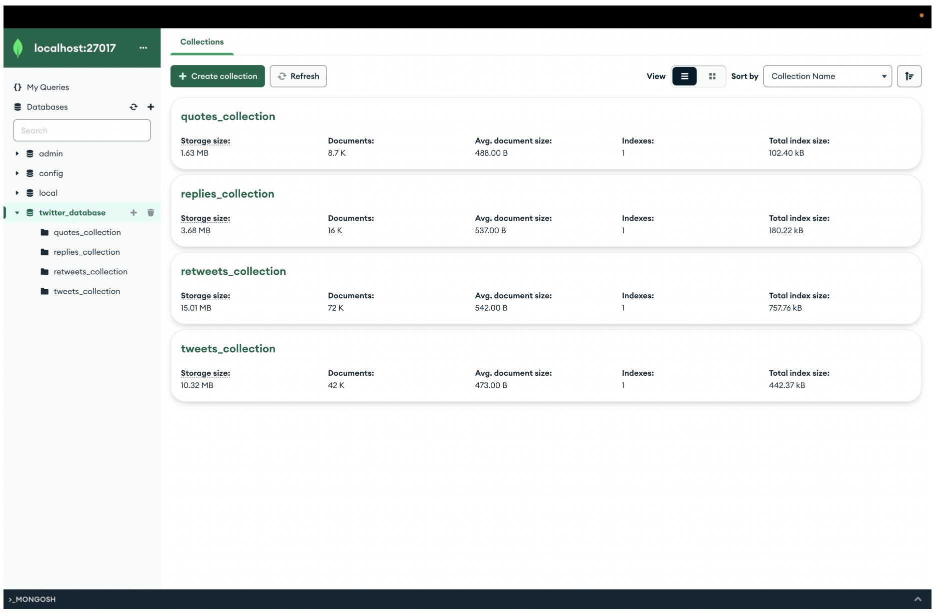
A complete tweet object looks complex with no fixed keys, as the 'retweeted_status,' 'quoted_status,' and others are unforced in every tweet. The data is handled with MongoDB, a non-relational database management system to overcome this. As the idea is to efficiently store the data for fast access, the data is stored in four collections in non-relational databases. MongoDB database is designed to store tweets, retweets, quoted tweets, and in_replies. Each collection in the tweets database holds the relevant data. While processing the data the duplicates are supervized.

- tweets collection - The tweets are stored in the database with the tweet as the unique Primary key and having 'id', 'text', 'created_at', 'source', 'retweet_count', 'favorite_count', 'lang', 'reply_count', 'user_id', 'hashtags' . The extended_tweet is also added to the tweet text if present.
- retweets collection - Retweets are handled by checking if the 'retweeted_status' key is present in the tweet object. If so, the code processes the retweet data and appends it to the 'retweets_list'. The original tweet (i.e., the tweet being retweeted) is also processed and stored in the 'tweets_list'. It also stores the original tweet user_id and the tweet_id.
- quoted_tweets collection - Quoted tweets are in the JSON 'quoted_status' array; if such tweets exist, they are stored in this database. The quoted_tweets stores all the features of tweets alongside the original tweet id and its user id and name to interact with other databases and fetch the original tweeted text.
- in_replies collection - This stores the user information, the in_reply text, and the status_id and user_id to which it is replied.

This MongoDB database keeps track of all the tweets at different levels and user ids, monitoring the conversations, tweets, and their reach.

3.3 Indexing

In this report, we discuss the indexing strategy employed for a search app utilizing both MySQL and MongoDB databases. Indexing helps improve the performance of query operations by creating an efficient



Collection	Storage size:	Documents:	Avg. document size:	Indexes:	Total index size:
quotes_collection	1.63 MB	8.7 K	488.00 B	1	102.40 kB
replies_collection	3.68 MB	16 K	537.00 B	1	180.22 kB
retweets_collection	15.01 MB	72 K	542.00 B	1	757.76 kB
tweets_collection	10.32 MB	42 K	473.00 B	1	442.37 kB

Figure 3: MongoDB server tweets processing compass

data structure to search for data in the database.

3.3.1 MySQL Indexing

In the users database in MySQL, indexing is created on the following fields.

MySQL Indexed Field	**Purpose**
‘id‘	Quickly search users by ID (e.g. tweets)
‘screen_name‘, ‘created_at_epoch‘, ‘followers_count‘	Speed up search, filter by date range and followers count, and sort by followers count
‘followers_count‘	Quickly sort users by followers count

Table 2: MySQL Index and Purpose

3.3.2 MongoDB Indexing

Indexing in MongoDB is as follows:

4 Search Application Design

The present developed Twitter Search App is based on the Streamlit application.

Streamlit Python: The Streamlit application, built using the Streamlit Python library, allows for the rapid development of interactive web applications. It enables the Twitter search application to connect

MongoDB Indexed Field	**Purpose**
‘user_id‘ and ‘created_at_edt‘	efficiently filter and sort tweets by user ID and creation date (e.g. tweets)
‘text‘, ‘created_at_epoch‘, and ‘retweet_count‘	Speed up search, filter by date range and followers count, and sort by followers count
‘retweet_count‘	sort tweets by retweet count
‘hashtags‘	speed up the aggregation of hashtags:
‘source‘	speed up the aggregation of sources
hashtags‘, ‘created_at_epoch‘, and ‘retweet_count	efficient hashtag search, date range filtering, and sorting by retweet count

Table 3: MongoDB Index and Purpose

to a data store containing information about Twitter users and their tweets. It then retrieves, processes, and displays the data based on user inputs, enabling users to explore various insights and trends.

4.1 Data Retrieval and Processing

A. **Retrieving data from the database**

1. **Top users by followers**
   The ‘get_top_users_by_followers()‘ function retrieves the top users based on their follower count. This function establishes a connection to the database, executes a query to fetch the top users in descending order of their follower count, and returns a list of dictionaries containing user data. The query also has a limit parameter that controls the number of top users to fetch.

2. **Top tweets by metric**
   The ‘get_top_tweets_by_metric()‘ function retrieves the top tweets based on a specified metric, such as retweet count or the favourite count. This function accepts the metric as an argument and fetches the corresponding data from the tweets_collection. It employs the pymongo ‘find()‘ method to obtain the tweets and the ‘sort()‘ method to order the results based on the given metric in descending order. The function returns a list of dictionaries containing tweet data.

B. **Processing and displaying data**

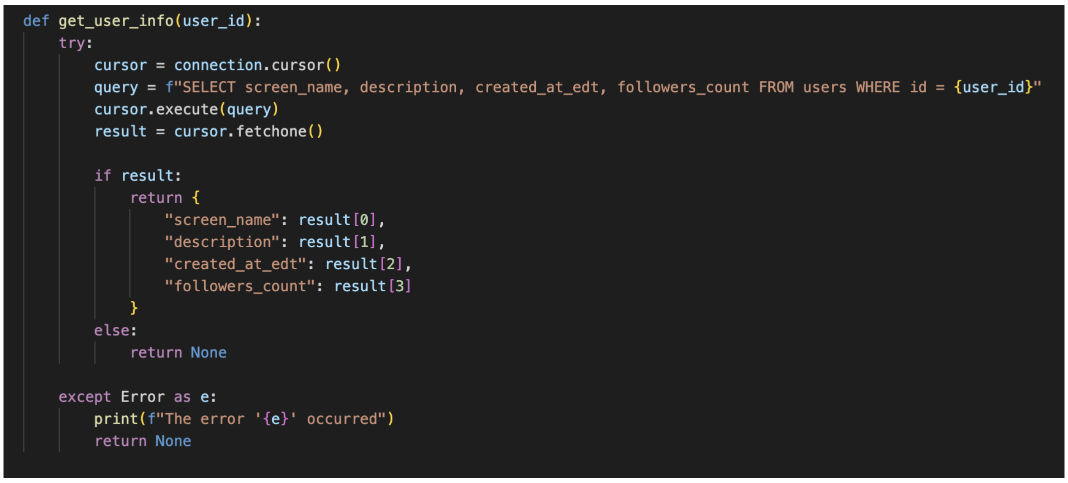
1. **Displaying top users**
   The ‘display_top_users()‘ function processes and displays the top users fetched by the ‘get_top_users_by_followe
   function. It iterates over the list of users, assigns a random avatar seed for each user, and generates an HTML representation of the user data using the ‘generate_user_html()‘ function.

2. **Displaying top tweets**
   The ‘display_top_tweets()‘ function processes and displays the top tweets obtained from the ‘get_top_tweets_by_metric()‘ function. The function retrieves the corresponding user information using the ‘get_user_info_with_cache()‘ function. The tweet data and user information are

then used to generate an HTML representation of the tweet using the ‘generate_tweet_html()‘ function.

3. **Displaying top hashtags**
   The ‘display_top_hashtags()‘ function retrieves the top hashtags using the ‘display_top_hashtags_helper_with_c function, which in turn calls the ‘display_top_hashtags_helper()‘ function. The function performs an aggregation operation on the tweets_collection using a pipeline that unwinds the hashtags, groups them, sorts them in descending order based on their count, and limits the number of results. The top hashtags and their counts are then displayed.

4. **Displaying top sources**
   The ‘display_top_sources()‘ function retrieves the top sources by executing the ‘display_top_sources_helper_wit function, which calls the ‘display_top_sources_helper()‘ function. This function performs an aggregation operation on the tweets_collection using a pipeline that groups the tweets by source, sorts them in descending order based on their count, and limits the number of results. The top sources and their counts are then displayed.



```python
def get_user_info(user_id):
    try:
        cursor = connection.cursor()
        query = f"SELECT screen_name, description, created_at_edt, followers_count FROM users WHERE id = {user_id}"
        cursor.execute(query)
        result = cursor.fetchone()

        if result:
            return {
                "screen_name": result[0],
                "description": result[1],
                "created_at_edt": result[2],
                "followers_count": result[3]
            }
        else:
            return None

    except Error as e:
        print(f"The error '{e}' occurred")
        return None
```

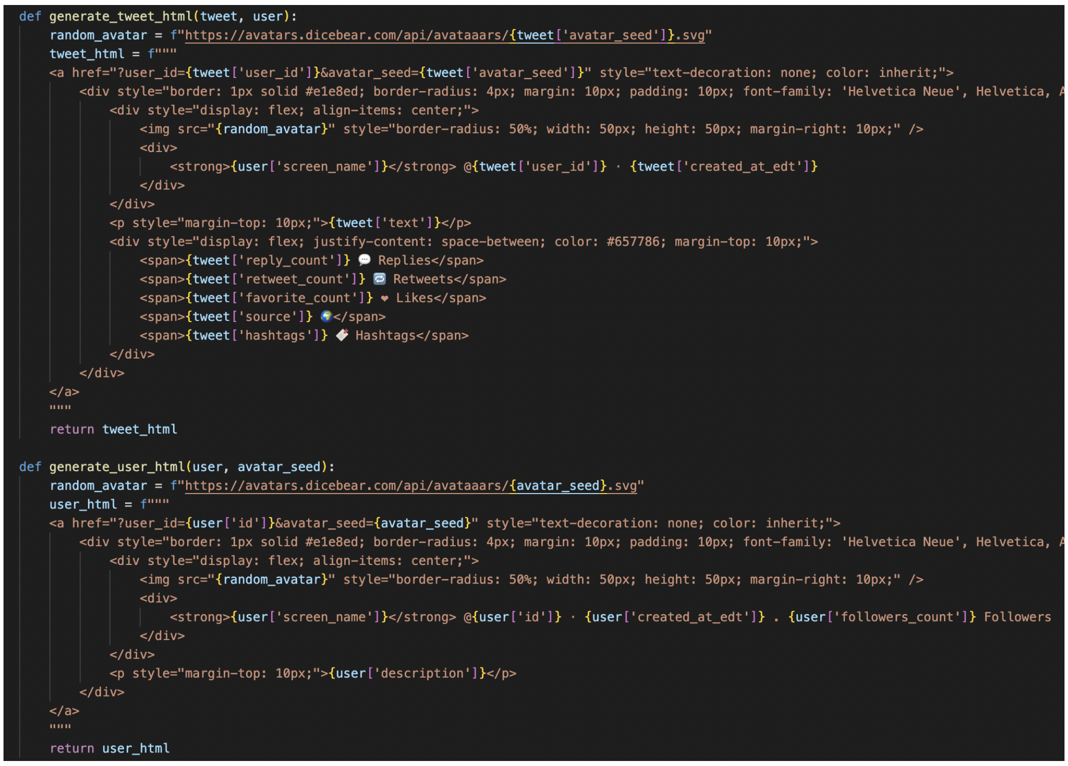
Figure 4: Example of search query - function to retreive user data from MySQL

4.2 Search and Filter Options

A. **Types of Searches Allowed**
   The application offers various search options to explore the data. Users can search within specific collections such as Users, Tweets, Retweets, Quoted tweets, Replies, and Hashtags. The application provides a sidebar with input fields for users to enter their desired search terms and choose a collection to search from.

B. **Drill-down Options**
   The application allows users to drill down and explore the data based on their selected search and filter criteria. The available drill-down options are:

   1. **Users**:
      This option displays a list of users matching the search criteria. Users can click on a specific user to view more information about that user, including their tweets.



```python
def generate_tweet_html(tweet, user):
    random_avatar = f"https://avatars.dicebear.com/api/avataaars/{tweet['avatar_seed']}.svg"
    tweet_html = f"""
    <a href="?user_id={tweet['user_id']}&avatar_seed={tweet['avatar_seed']}" style="text-decoration: none; color: inherit;">
        <div style="border: 1px solid #e1e8ed; border-radius: 4px; margin: 10px; padding: 10px; font-family: 'Helvetica Neue', Helvetica, A
            <div style="display: flex; align-items: center;">
                <img src="{random_avatar}" style="border-radius: 50%; width: 50px; height: 50px; margin-right: 10px;" />
                <div>
                    <strong>{user['screen_name']}</strong> @{tweet['user_id']} · {tweet['created_at_edt']}
                </div>
            </div>
            <p style="margin-top: 10px;">{tweet['text']}</p>
            <div style="display: flex; justify-content: space-between; color: #657786; margin-top: 10px;">
                <span>{tweet['reply_count']} 💬 Replies</span>
                <span>{tweet['retweet_count']} 🔁 Retweets</span>
                <span>{tweet['favorite_count']} ❤ Likes</span>
                <span>{tweet['source']} 🌍</span>
                <span>{tweet['hashtags']} 🏷️ Hashtags</span>
            </div>
        </div>
    </a>
    """
    return tweet_html

def generate_user_html(user, avatar_seed):
    random_avatar = f"https://avatars.dicebear.com/api/avataaars/{avatar_seed}.svg"
    user_html = f"""
    <a href="?user_id={user['id']}&avatar_seed={avatar_seed}" style="text-decoration: none; color: inherit;">
        <div style="border: 1px solid #e1e8ed; border-radius: 4px; margin: 10px; padding: 10px; font-family: 'Helvetica Neue', Helvetica, A
            <div style="display: flex; align-items: center;">
                <img src="{random_avatar}" style="border-radius: 50%; width: 50px; height: 50px; margin-right: 10px;" />
                <div>
                    <strong>{user['screen_name']}</strong> @{user['id']} · {user['created_at_edt']} . {user['followers_count']} Followers
                </div>
            </div>
            <p style="margin-top: 10px;">{user['description']}</p>
        </div>
    </a>
    """
    return user_html
```

Figure 5: Rendering individual tweets and users using HTML

2. **Tweets**:
   This option shows a list of tweets matching the search criteria, ordered by their retweet count. Users can click on a specific tweet to view more information about that user, including their tweets, quoted tweets and replies.

3. **Retweets**:
   This option displays a list of retweeted tweets matching the search criteria, ordered by their retweet count. Users can click on a specific retweet to view more information about that user, including their tweets, quoted tweets and replies

4. **Quoted tweets**:
   This option shows a list of quoted tweets matching the search criteria, ordered by their retweet count. Users can click on a specific quoted tweet to view more information about that user, including their tweets, quoted tweets and replies

5. **Replies**:
   This option displays a list of reply tweets matching the search criteria, ordered by their retweet count. Users can click on a specific reply to view more information about that user, including their tweets, quoted tweets and replies

6. **Hashtags**: This option shows a list of tweets containing the searched hashtags, ordered by their retweet count. Users can click on a specific tweet to view more information about that user, including their tweets, quoted tweets and replies

C. **Date Range Filtering**:

The application provides date range filtering, enabling users to narrow down their search results based on a specific time frame. Users can select start and end dates using the sidebar's date input fields. The application will display search results within the specified date range, allowing users to focus on data relevant to their desired time period.

4.3 Query Translation

A. **Translating Search Queries into Database Queries**
The application translates search queries into appropriate database queries to fetch relevant data from the underlying datastores. Depending on the collection filter selected by the user, the application constructs different queries using the search term and date range provided by the user. For instance, when searching within the "Hashtags" collection, the application uses regular expressions in the query to match the search term with the hashtags present in the tweets.

B. **Examples of Query Translations**

1. **Hashtags search**:
When searching for a hashtag, the application constructs a query with the search term and date range. The query looks like this:

```
{
'hashtags': {'$elemMatch': {'$regex': search_string, '$options': 'i'}},
'created_at_epoch': {'$gte': date_range[0], '$lte': date_range[1]}
}
```

2. **Users search**:
When searching for users, the application constructs a query with the search term and date range. The query looks like this:

```
{
   '$or': [
      {'screen_name': {'$regex': search_string, '$options': 'i'}},
      {'description': {'$regex': search_string, '$options': 'i'}}
   ],
   'created_at_epoch': {'$gte': date_range[0], '$lte': date_range[1]}
}
```

4.4 Relevance and Result Ordering

A. **Defining Relevance in the Application**
Relevance in the application is determined by the search term, collection filter, and date range specified by the user. The application considers results relevant if they match the search term and fall within the specified date range.

B. **Ordering Search Results**
The search results are ordered based on the collection filter and specific metric selected by the user. For example:

1. **Tweets/Retweets/Quoted Tweets/Replies**:
When searching within the user selected filter collection, the results are ordered by retweet count in descending order.

2. **Users**:
When searching for "Top Users by followers count", the results are ordered by the number of followers in descending order. For a specific user, the tweets are displayed in the decreasing order of created date.

5 Caching

Cache implementation in the application: The application employs a caching mechanism to enhance its performance and efficiency. It uses the LRU ‘cache‘ to cache the results of various functions that involve retrieving data from the datastore or performing expensive computations.

Code Overview:

The code defines a class `LRUCache` with the following methods:

(a) `init(self, capacity, checkpoint_file, checkpoint_interval, ttl=None)`: Initializes the cache with the specified capacity, checkpoint file, checkpoint interval, and optional time-to-live (TTL).

(b) `_evict(self)`: Evicts the least recently used item from the cache.

(c) `get(self, key)`: Returns the value associated with the given key, updating its access time.

(d) `put(self, key, value)`: Stores the key-value pair in the cache, evicting the least recently used item if the cache is full.

(e) `load_cache(self)`: Loads the cache from the checkpoint file if it exists.

(f) `checkpoint(self)`: Writes the cache to the checkpoint file.

(g) `purge_stale_entries(self)`: Removes cache entries that have exceeded their TTL (if provided).

(h) `start_periodic_checkpoint(self)`: Starts an infinite loop to periodically checkpoint the cache and purge stale entries based on the specified checkpoint interval.

Key Features:

(a) **Capacity**: The cache is initialized with a specific capacity, which determines the maximum number of items it can store.

(b) **Persistence**: The cache can be persisted to a file through the use of checkpointing, which saves and loads the cache from a specified file.

(c) **Automatic Checkpointing**: Checkpointing occurs periodically, as determined by the specified checkpoint interval.

(d) **Time-to-live (TTL)**: An optional TTL can be provided during cache initialization, which will cause entries to be removed if they have not been accessed within the specified duration.

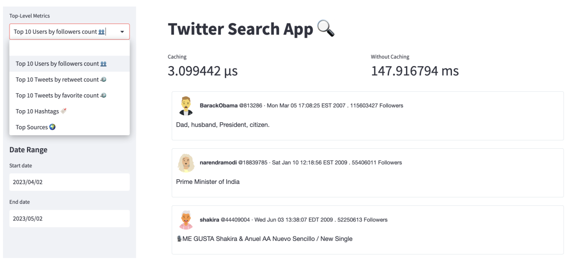
For instance, the ‘get_top_users_by_followers_with_cache()‘ function utilizes caching to store and reuse the results of the ‘get_top_users_by_followers()‘ function, which fetches the top users by follower count from the datastore. Similarly, caching is implemented in functions like ‘get_top_tweets_by_metric_with_cache()‘, ‘display_top_hashtags_helper_with_cache()‘, and ‘display_top_sources_helper_with_cache()‘ to optimize their performance.

The caching mechanism also measures the time taken to retrieve results from the cache versus the time taken to perform the operation without caching. This allows for a comparison of response times, demonstrating the significant performance improvement the caching technique offers.

Implementing caching in the application ensures that the results of expensive operations are reused whenever possible, leading to faster response times, reduced computational overhead, and an overall better user experience.

6 Results

Figure 6 shows the results of search queries performed by the user on the search application, it includes with and without caching. It is noticed that the cached results and without cached results have a time difference of an order of 100 milli seconds or 100,000 micro seconds difference.


Top-Level Metrics
Top 10 Users by followers count
Top 10 Users by followers count
Top 10 Tweets by retweet count
Top 10 Tweets by favorite count
Top 10 Hashtags
Top Sources
Date Range
Twitter Search App

Start date 2023/04/02
End date 2023/05/02

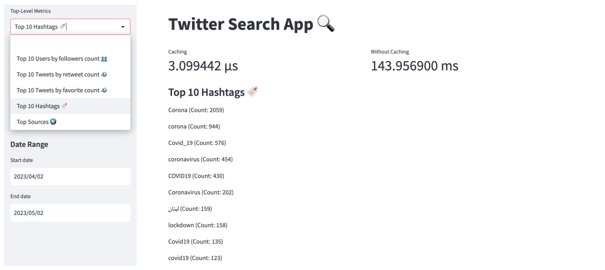
Caching 3.099442 µs
Without Caching 147.916794 ms

BarackObama @813286 · Mon Mar 05 17:08:25 EST 2007 . 115603427 Followers
Dad, husband, President, citizen.

narendramodi @18839785 · Sat Jan 10 12:18:56 EST 2009 . 55406011 Followers
Prime Minister of India

shakira @44409004 · Wed Jun 03 13:38:07 EDT 2009 . 52250613 Followers
ME GUSTA Shakira & Anuel AA Nuevo Sencillo / New Single

(a) Top 10 users by followers count


Top-Level Metrics
Top 10 Hashtags
Top 10 Users by followers count
Top 10 Tweets by retweet count
Top 10 Tweets by favorite count
Top 10 Hashtags
Top Sources
Date Range
Twitter Search App

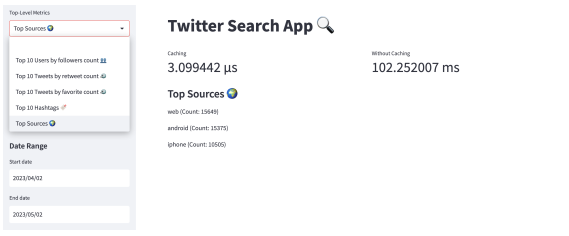
Start date 2023/04/02
End date 2023/05/02

Caching 3.099442 µs
Without Caching 143.956900 ms

Top 10 Hashtags

Corona (Count: 2059)
corona (Count: 944)
Covid_19 (Count: 576)
coronavirus (Count: 454)
COVID19 (Count: 430)
Coronavirus (Count: 202)
لبنان (Count: 159)
lockdown (Count: 158)
Covid19 (Count: 135)
covid19 (Count: 123)

(b) Top 10 Hashtags by count


Top-Level Metrics
Top Sources
Top 10 Users by followers count
Top 10 Tweets by retweet count
Top 10 Tweets by favorite count
Top 10 Hashtags
Top Sources
Date Range
Twitter Search App

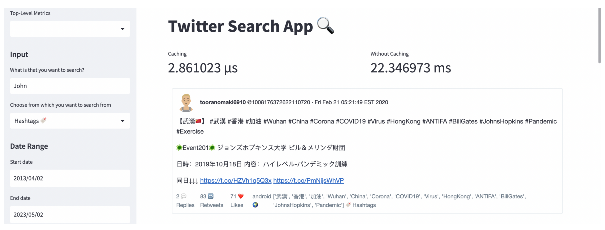
Start date 2023/04/02
End date 2023/05/02

Caching 3.099442 µs
Without Caching 102.252007 ms

Top Sources

web (Count: 15649)
android (Count: 15375)
iphone (Count: 10505)

(c) Top Sources by their count

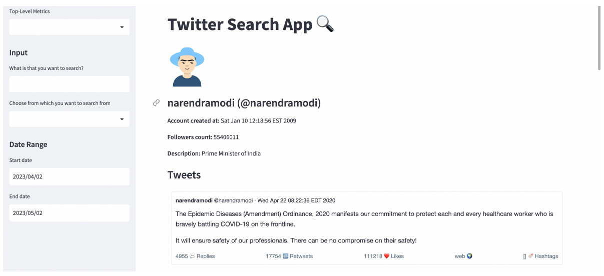


What is that you want to search? John
Choose from which you want to search from Hashtags
Start date 2013/04/02
End date 2023/05/02

Caching 2.861023 µs
Without Caching 22.346973 ms

tooranomaki6910 @1008176372622110720 · Fri Feb 21 05:21:49 EST 2020
【武漢】 #武漢 #香港 #加油 #Wuhan #China #Corona #COVID19 #Virus #HongKong #ANTIFA #BillGates #JohnsHopkins #Pandemic #Exercise
Event201 ジョンズホプキンス大学 ビル＆メリンダ財団
日時：2019年10月18日 内容：ハイレベル-パンデミック訓練
同日↓↓↓ https://t.co/HZVh1q5Q3x https://t.co/PmNjjsWhVP
2 Replies 83 Retweets 71 Likes android ['武漢', '香港', '加油', 'Wuhan', 'China', 'Corona', 'COVID19', 'Virus', 'HongKong', 'ANTIFA', 'BillGates', 'JohnsHopkins', 'Pandemic'] Hashtags

(d) Search for 'John' in Hashatgs


Top-Level Metrics
Input
What is that you want to search?
Choose from which you want to search from
Date Range
Twitter Search App

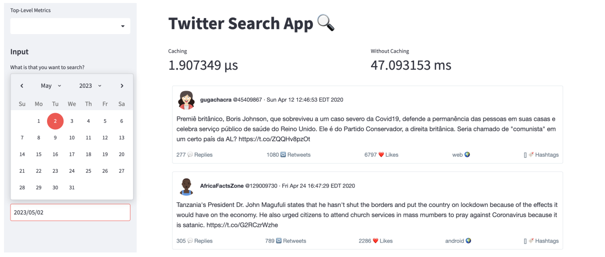
Start date 2023/04/02
End date 2023/05/02

narendramodi (@narendramodi)
Account created at: Sat Jan 10 12:18:56 EST 2009
Followers count: 55406011
Description: Prime Minister of India

Tweets

narendramodi @narendramodi · Wed Apr 22 08:22:36 EDT 2020
The Epidemic Diseases (Amendment) Ordinance, 2020 manifests our commitment to protect each and every healthcare worker who is bravely battling COVID-19 on the frontline.
It will ensure safety of our professionals. There can be no compromise on their safety!
4955 Replies 17754 Retweets 111218 Likes web [] Hashtags

(e) Top Sources by their count



2023/05/02

Caching 1.907349 µs
Without Caching 47.093153 ms

gugachacra @45409867 · Sun Apr 12 12:46:53 EDT 2020
Premiê britânico, Boris Johnson, que sobreviveu a um caso severo da Covid19, defende a permanência das pessoas em suas casas e celebra serviço público de saúde do Reino Unido. Ele é do Partido Conservador, a direita britânica. Seria chamado de "comunista" em um certo país da AL? https://t.co/ZQQHv8pzOt
277 Replies 1080 Retweets 6797 Likes web [] Hashtags

AfricaFactsZone @129009730 · Fri Apr 24 16:47:29 EDT 2020
Tanzania's President Dr. John Magufuli states that he hasn't shut the borders and put the country on lockdown because of the effects it would have on the economy. He also urged citizens to attend church services in mass mumbers to pray against Coronavirus because it is satanic. https://t.co/G2RCzrWzhe
305 Replies 789 Retweets 2286 Likes android [] Hashtags

(f) Search for 'John' in Hashatgs

Figure 6: Screenshots of the results we obtain with caching

7 Conclusion

The Twitter search app design offers a user-friendly interface for searching and filtering data from a Twitter-like database. It supports various search options, drill-downs, and date range filtering to help users explore the data effectively. Our current design covers the salient features and brings inventiveness by using avatar and the layouts. The experimental framework leverages caching to improve performance and query execution times. Moreover, it defines relevance based on user-specified search criteria and orders the results accordingly. The implementation showcases an efficient way to search and explore data within a large datasets. Application also supports multiple search options, filters, and result ordering, the application caters to various user needs and preferences.

Building Twitter search app has been a fun and a big learning experience. Explored various database architectures handling volumes of data which are integrated to design search applications. Discovered the significance of Database Management Systems and Caching for Applications.

8 Work Contribution

TeamMember	Contribution
Neha	Relational Database - Users data using MySQL
Manisha	Non Relational Database - Tweets data using MongoDB, Indexing on databases
Vivek	Interface and Search Application Design, Connection to databases, Caching