Analysis of New York Taxi Trips

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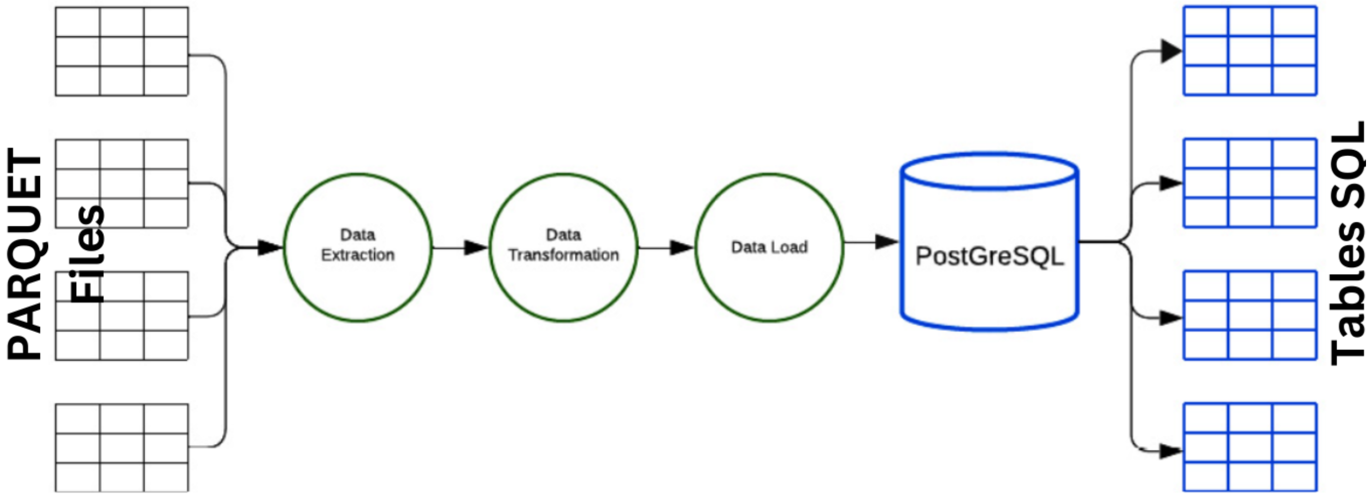
Introduction

The transportation sector, particularly taxi service, is a crucial part of New York's urban infrastructure. With millions of trips taken each year, the data generated by these trips provides a wealth of valuable information. This Data Science project aims to explore and analyze New York City taxi trip data, collected by the New York City Taxi and Limousine Commission (TLC), with the aim of generating actionable insights and developing predictive models using Machine Learning techniques.

Scenario

A newly hired Data Scientist at a transportation analytics firm embarks on a project to analyze New York City taxi trip data sourced from the NYC Taxi and Limousine Commission (TLC). The dataset includes detailed records of yellow and green taxi trips, as well as For-Hire Vehicle (FHV) trip records. The goal of the project is to extract valuable insights from the vast amount of trip data, ultimately contributing to optimizing transportation services and informing policy decisions.

Part 1 : Data Collection and ETL Process for Loading Data into a PostgreSQL Database



The first stage of this project involves collecting taxi trip data from New York City from the official source provided by the NYC Taxi and Limousine Commission (TLC). This collection requires a thorough understanding of TLC's policies and regulations regarding data usage.

Once the data is collected, the Extract, Transform, Load (ETL) process is initiated to prepare the data for integration into a PostgreSQL database. Here are the detailed steps of the ETL process:

Extraction:

The data is extracted from the source files downloaded from the TLC website (https://www.nyc.gov/site/tlc/about/tlc-trip-record-data.page). Actually, these files are in PARQUET format like specified by the source.

Transformation:

Once the data is extracted, it undergoes transformations to clean, structure, and prepare it for loading into the database. Transformations may include cleaning the data by removing duplicates, correcting format errors, or handling missing values. The data structure may also be modified to match the schema of the target database. For example, fields may be renamed, reformatted, or combined as needed for analysis.

Loading:

Once the data is cleaned and transformed, it is loaded into a PostgreSQL database. Before loading, the Data Scientist creates an appropriate database schema to store the taxi trip data. This involves defining tables, columns, and constraints necessary to ensure data integrity. The data is loaded into the database using suitable tools and programming languages, such as psycopg2 (for Python) or SQL commands.

Once this first part is completed, all taxi trip data will be integrated and ready for exploration and analysis in the PostgreSQL database. This process ensures that the data is organized efficiently and consistently, facilitating the subsequent steps of data analysis.

Setting Up the Local Environment for Data Loading Activities into PostgreSQL

- Open pgAdmin 4.
- In the *Quick Links* section, click on *Add New Server*. Here are the details to fill in:
    - Name: ytaxi_ETL

    - Host: localhost
    - Port: 5432 (default value)
    - User: postgres (default value)
    - Password: enter your password

To create a database:

- Click on the server you just created.
- Right-click on *Databases*, then select *Create > Database*.
- Name: nyc_yellow_taxi_record

Here is the SQL code that generates the database *nyc_yellow_taxi_record*:

```
CREATE DATABASE nyc_yellow_taxi_record
    WITH
    OWNER = postgres
    ENCODING = 'UTF8'
    CONNECTION LIMIT = -1
    IS_TEMPLATE = False;

COMMENT ON DATABASE nyc_yellow_taxi_record
    IS 'Database for yellow taxi trips in New York City';
```

Here is the SQL code to create the table *ytaxi_histo* (using the PSQL tool in pgAdmin4):

```
CREATE TABLE ytaxi_histo (
    VendorID int NOT NULL,
    tpep_pickup_datetime timestamp NOT NULL,
    tpep_dropoff_datetime timestamp NOT NULL,
    passenger_count float NOT NULL,
    trip_distance float NOT NULL,
    RatecodeID float NOT NULL,
    store_and_fwd_flag varchar(1) NOT NULL,
    PULocationID int NOT NULL,
    DOLocationID int NOT NULL,
    payment_type int NOT NULL,
    fare_amount float NOT NULL,
    extra float NOT NULL,
    mta_tax float NOT NULL,
    tip_amount float NOT NULL,
    tolls_amount float NOT NULL,
    improvement_surcharge float NOT NULL,
    total_amount float NOT NULL,
    congestion_surcharge float NOT NULL,
    Airport_fee float NOT NULL
);
```

Establishing Connection to a PostgreSQL Table to Retrieve Data

Begin by installing the necessary packages:

```
pip install sqlalchemy
pip install psycopg2-binary
```

```python
from sqlalchemy import create_engine

# Define the connection information to the database
db_user = 'postgres'
db_password = '' # Enter your password
db_host = 'localhost'  # or the IP address of the database server
db_port = '5432'  # Default port for PostgreSQL
db_name = 'nyc_yellow_taxi_record'

# Create a connection to the database
engine = create_engine(f'postgresql://{db_user}:{db_password}@{db_host}:{db_port}/{db_name}')

# Name of the table to read
table_name = 'ytaxi_histo'

# Read data from the table into a DataFrame
df = pd.read_sql_table(table_name, con=engine)

# Display the first few rows of the DataFrame
print(df.head())
```

Script to download and save data files: *download_data_files.py

This Python script `download_taxi_data.py` is designed to download yellow taxi trip data files in PARQUET format from 2019 to the current year and save them into a specified folder.

Here's a breakdown of the code:

- **Importing Libraries**: The script imports necessary libraries such as `os`, `requests`, `time`, `hashlib`, and `datetime`.
- **`download_histo_data` Function**: This function is defined to handle the download process. It takes one argument:
  - `path_to_histo_data_folder`: A string representing the path to the folder where the files will be saved.
- **Try-Except Block**: The main code is wrapped in a try-except block to catch and handle any potential errors that may occur during execution.

- **Creating Folder**: It checks if the folder specified by `path_to_histo_data_folder` exists. If not, it creates the folder using `os.makedirs()`.
- **Looping Over Years and Months**: It loops over the years from the current year to 2019 and for each year, it iterates over the months from January to December.
- **Constructing Download URL**: It constructs the download URL based on the year and month.
- **Checking File Existence**: It checks if the file already exists in the specified folder. If it does, it prints a message and skips to the next file.
- **Downloading File**: It attempts to download the file using `requests.get()` with error handling. If the download is successful (HTTP status code 200), it writes the content to a file in binary mode.
- **Pausing Between Downloads**: To avoid overloading the remote server, it pauses for 1 second between each download using `time.sleep(1)`.
- **Printing Completion Message**: Once all downloads are completed or if an error occurs, it prints a completion message.
- **Date Information**: It prints the date of the day when the historical data download is initiated.
- **Path to Save Data**: It specifies the path to the folder where historical data will be saved.
- **Function Call**: Finally, it calls the `download_histo_data` function with the specified path to download the historical data.

This script automates the process of downloading historical taxi trip data files, ensuring the availability of up-to-date data for analysis.

ETL Functions/Scripts

- ***etl_functions.py***

1. **`extract(file_path)` Function**:
   - **Purpose**: This function is responsible for extracting data from a Parquet file and returning a pandas DataFrame.
   - **Parameters**:
     - `file_path (str)`: The path to the Parquet file.
   - **Returns**:
     - `pandas.DataFrame`: DataFrame containing the data from the Parquet file.
   - **Description**:
     - It sets up logging to record any information or errors during the extraction process.
     - Reads the Parquet file into a DataFrame using `pd.read_parquet()`.
     - Logs a success message if the extraction is successful and returns the DataFrame.
     - If any error occurs during the extraction process, it logs the error and returns `None`.

2. **`transform(df)` Function**:
   - **Purpose**: This function filters the DataFrame by removing observations with missing values in 'passenger_count' and 'total_amount' columns.

- **Parameters**:
    - `df (pandas.DataFrame)`: Input DataFrame.
- **Returns**:
    - `pandas.DataFrame`: Filtered DataFrame.
- **Description**:
    - It sets up logging to record any information or errors during the transformation process.
    - Drops all rows with missing values using `df.dropna(axis=0)`.
    - Corrects the column names to lowercase using `df.rename(columns=str.lower)`.
    - Logs a success message if the transformation is successful and returns the filtered DataFrame.
    - If any error occurs during the transformation process, it logs the error and returns `None`.

3. **`load(df, table_name, connection_string)` Function**:

    - **Purpose**: This function loads data from a DataFrame into a PostgreSQL table.
    - **Parameters**:
        - `df (pandas.DataFrame)`: Input DataFrame.
        - `table_name (str)`: Name of the PostgreSQL table to load the data into.
        - `connection_string (str)`: PostgreSQL connection string.
    - **Returns**:
        - `bool`: True if data loading is successful, False otherwise.
    - **Description**:
        - It sets up logging to record any information or errors during the loading process.
        - Creates a database engine using the provided connection string.
        - Loads the DataFrame into the specified PostgreSQL table using `df.to_sql()`.
        - Closes the database connection using `engine.dispose()`.
        - Logs a success message if the data loading is successful and returns `True`.
        - If any error occurs during the loading process, it logs the error and returns `False`.

etl_pipeline.py

Here's a detailed breakdown of the `etl_pipeline.py` script:

1. **Imports**:

    - `os`: Provides functions to interact with the operating system, such as manipulating file paths.
    - `logging`: Enables logging functionality to record information or errors during script execution.
    - `etl_functions`: Contains custom functions for the ETL (Extract, Transform, Load) pipeline.

2. **Setting up Logging**:

    - Configures logging settings to write log messages to a file named `run_pipeline.log`.
    - Log messages include timestamps, log levels, and message content.

3. **Variables Initialization**:

    - `path_to_histo_data_folder`: Specifies the path to the folder containing historical data Parquet files.

    - `connection_string`: Defines the PostgreSQL connection string, including username, password, host, port, and database name.

4. **`run_pipeline` Function**:

    - **Purpose**: Executes the historical data ETL pipeline.
    - **Parameters**:
        - `path_to_histo_data_folder (str)`: Path to the folder containing historical data Parquet files.
        - `connection_string (str)`: PostgreSQL connection string.
    - **Steps**:
        - Lists all Parquet files in the specified folder.
        - For each Parquet file:
            - Constructs the full file path.
            - Extracts data from the Parquet file using `etl_functions.extract()`.
            - Transforms the extracted data using `etl_functions.transform()`.
            - Loads the transformed data into PostgreSQL using `etl_functions.load()` if transformation is successful.
        - Logs appropriate messages for each step, including success or failure.
    - **Error Handling**:
        - Catches and logs any exceptions that occur during the pipeline execution.

5. **Execution**:

    - Sets up database connection information.
    - Calls the `run_pipeline` function with the specified parameters (`path_to_histo_data_folder` and `connection_string`).

This script orchestrates the entire ETL process for historical data, including extraction, transformation, and loading into a PostgreSQL database. It ensures data consistency and integrity while providing detailed logging for monitoring and troubleshooting purposes.

Order of execution of part 1

From the terminal, run these commands :

1.

```
python3 download_data_files.py
```

2.

```
python3 etl_pipeline.py
```

Requirements for part 1

numpy==1.26.4 pandas==2.2.2 psycopg2-binary==2.9.9 pyarrow==16.0.0 requests==2.31.0 SQLAlchemy==2.0.30

For data from January 2019 to February 2024, my table contains 106 197 954 rows.