Spring 2025 CS307 Project1

OurTeam

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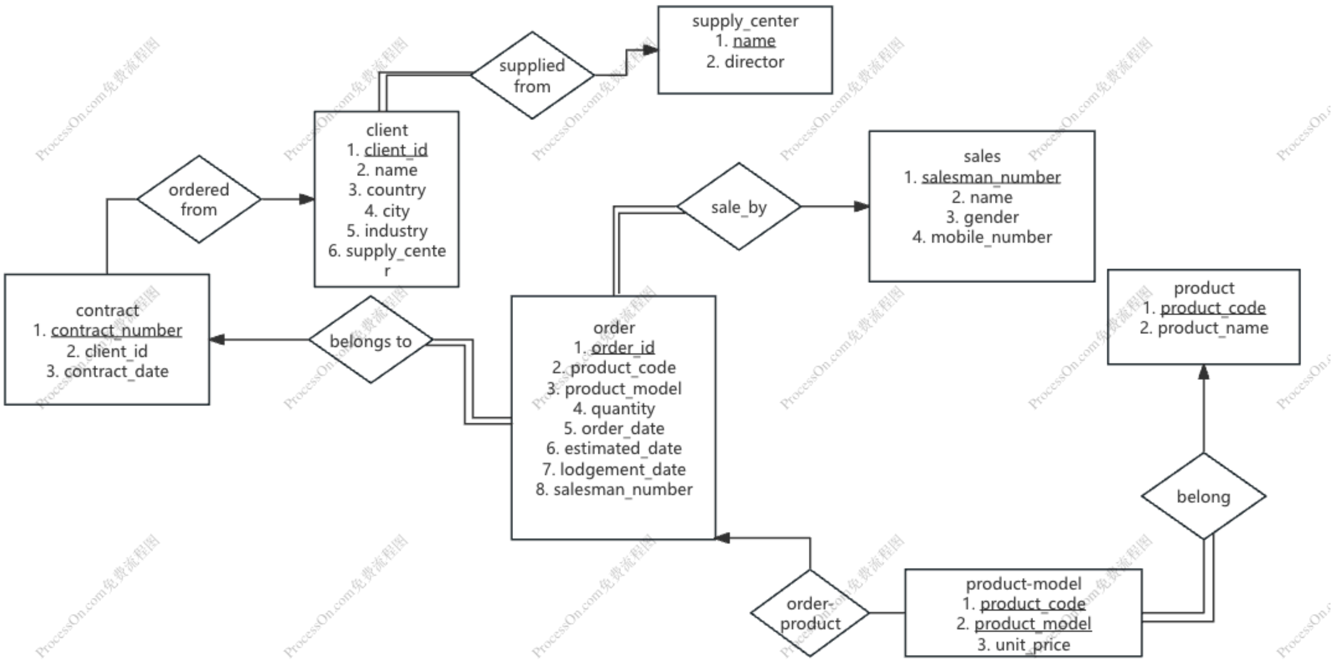
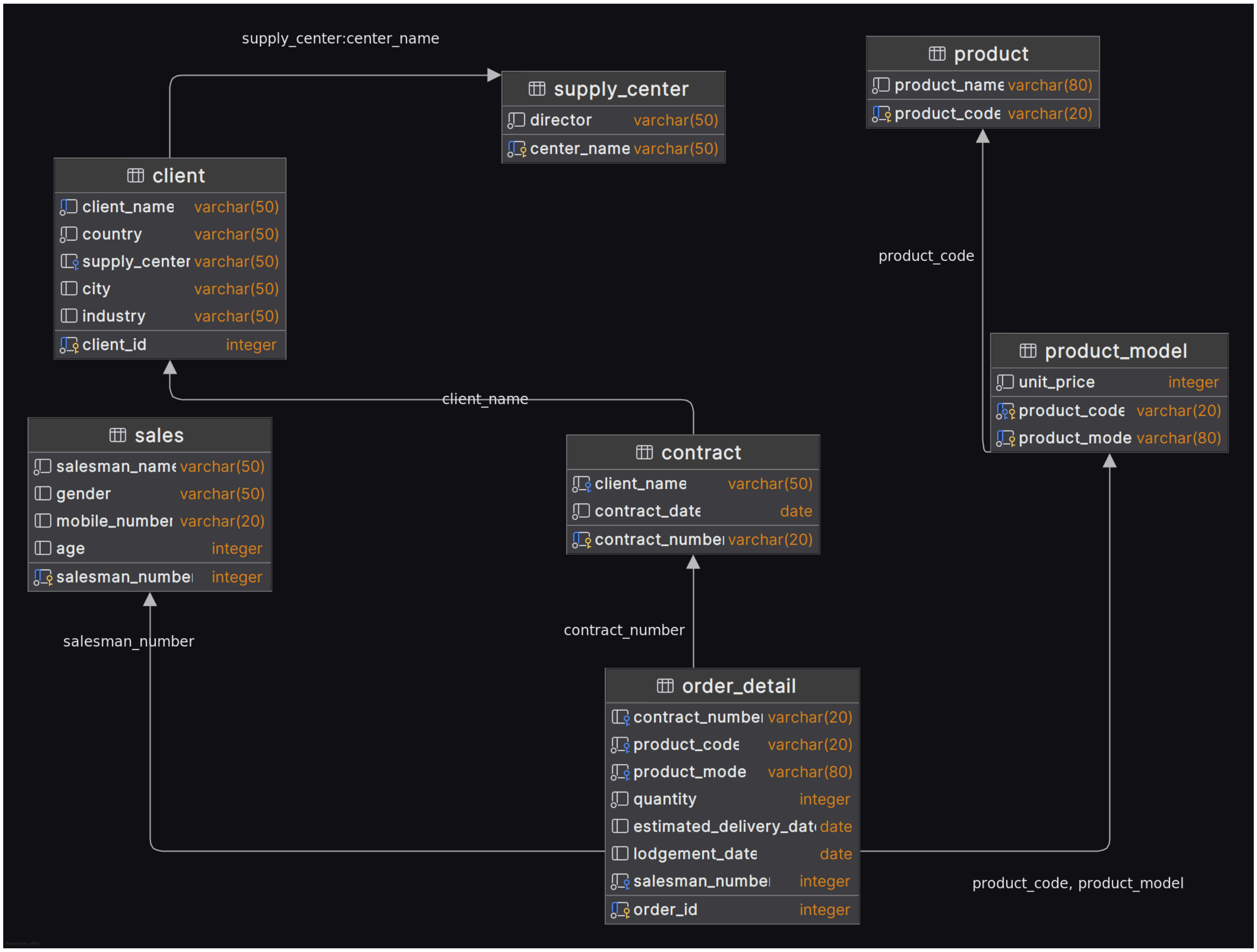
Task: Python script C++ script write paper	Task: Design E-R Diagram Java script write paper
Percentage of contribution: 50%	Percentage of contribution: 50%

E-R diagram



- The E-R diagram is drawn on the processon

DataGrip Diagram



Database Design

(create table statements file is in `/create_table.sql`)

Content Description

1. supply_center

- **Purpose**: Stores information about supply centers.
- **Columns**:
  - `center_name` (Primary Key): Unique name of the supply center.
  - `director`: Name of the director managing the center.

2. `client`

- **Purpose**: Stores client details and their associated supply centers.
- **Columns**:
  - `client_id` (PK): Auto-incremented unique identifier for the client.

  - `client_name`: Unique name of the client.
  - `country`, `city`, `industry`: Geographic and business details of the client.
  - `supply_center` (Foreign Key): Links the client to their assigned supply center, which is defined by clients country.

3. `contract`

- **Purpose**: Stores contracts basic info.
- **Columns**:
  - `contract_number` (PK): Unique identifier for the contract.
  - `client_name` (Foreign Key): References the client who signed the contract.
  - `contract_date`: Date when the contract was signed.

4. `sales`

- **Purpose**: Stores salesman details.
- **Columns**:
  - `salesman_number` (PK): Unique identifier for the salesman.
  - `salesman_name`: Name of the salesperson.
  - `gender`, `age`, `mobile_number`: Basic information of the salesman.

5. `product`

- **Purpose**: Stores basic product information.
- **Columns**:
  - `product_code` (PK): Unique code for the product.
  - `product_name`: Descriptive name of the product.

6. `product_model`

- **Purpose**: Stores specific models of a product and their unit price.
- **Columns**:
  - `product_code` (PK/FK): Links to the parent product (`product.product_code`).
  - `product_model` (PK): Name of the model (e.g., "Pro Max 256GB").
  - `unit_price`: Price per unit for the model.

7. `order_detail`

- **Purpose**: Captures detailed information about individual orders.
- **Columns**:

- `order_id` (PK): Auto-incremented unique identifier for the order.
- `contract_number` (FK): Links the order to its parent contract.
- `product_code` + `product_model` (Composite FK): Specifies the product model ordered.
- `quantity` : Number of units ordered.
- `estimated_delivery_date` : Planned delivery date.
- `lodgement_date` : Actual delivery date.
- `salesman_number` (FK): Salesperson responsible for the order.

Data Import

Java

in `src/javaImplementation`

Script name	Author	Description
/Java/Load.java	Yao Shengqi	The main function. Run this with parameters
/Java/LowLoad.java	Yao Shengqi	The class that imports the data in serial
/Java/ConcurrentLoad.java	Yao Shengqi	The class that imports the data concurrently
/Java/PrepareTool.java	Yao Shengqi	The class that provides preparing method

How to use

1. Import all the .jar file in `/dependencies` . Notice the postgresql dependency is not included.
2. Use `create_table.sql` to create table.
3. Modify the `resources/dbUser.properties` . Edit the 'database', 'user', 'pwd', 'port'
4. Move the original (or modified) .csv file under path `/resources` . Rename the file `output25S.csv`
5. Open `/src/Java/Load.java` , run with parameters:
    1. `0` concurrent mode
    2. `1` serial mode

Python

in `src/Python`

Script name	Author	Description
load_single.py	Wei Guoxin	Import data by insert them in turn
load_parallel.py	Wei Guoxin	A parallel version of the above code
load_imp_single.py	Wei Guoxin	Optimized version of import data
load_imp_par.py	Wei Guoxin	A parallel version of the above code

How to use

1. Use conda to create a environment `database`
2. Use pip to get psycopg2 and pandas
3. run the selected script

C++

in `src/C++`

Script name	Author	Description
load_single.cpp	Wei Guoxin	Import data by insert them in turn
load_parallel.cpp	Wei Guoxin	A parallel version of the above code
load_imp_sin.cpp	Wei Guoxin	Optimized version of import data
load_imp_par.cpp	Wei Guoxin	A parallel version of the above code

How to use

1. Begin by reading the `env.txt` file, which contains critical environment variables and settings required for the project.
2. Utilize `cmake` to generate build files tailored for your specific system and compiler.
3. use `make` to compile the source code into an executable file
4. Once the executable is built, run the program to initiate the data import process.

Advanced

Optimization

Java

- **Data Parsing and Storing**: Initially, the script parses the input data and stores it into a list structure. This list serves as a temporary repository that holds the data before it is imported into the database.
- **Concurrent Batch Imports**: The data is then imported in three separate concurrent batches. This approach is based on the parent-child relationships between different tables within the database.
- **Order Details Import**: The third batch is dedicated exclusively to importing the `order_details` table. This is a critical step because the `order_details` table often contains a large volume of data that needs to be processed.
- **Sub-Batching for Multi-Threaded Import**: To further enhance the efficiency of the import process, the list containing `order_details` data is split into multiple sub-batches. These sub-batches are then imported concurrently using multi-threading, which helps to distribute the workload and reduce the total import time.

Python

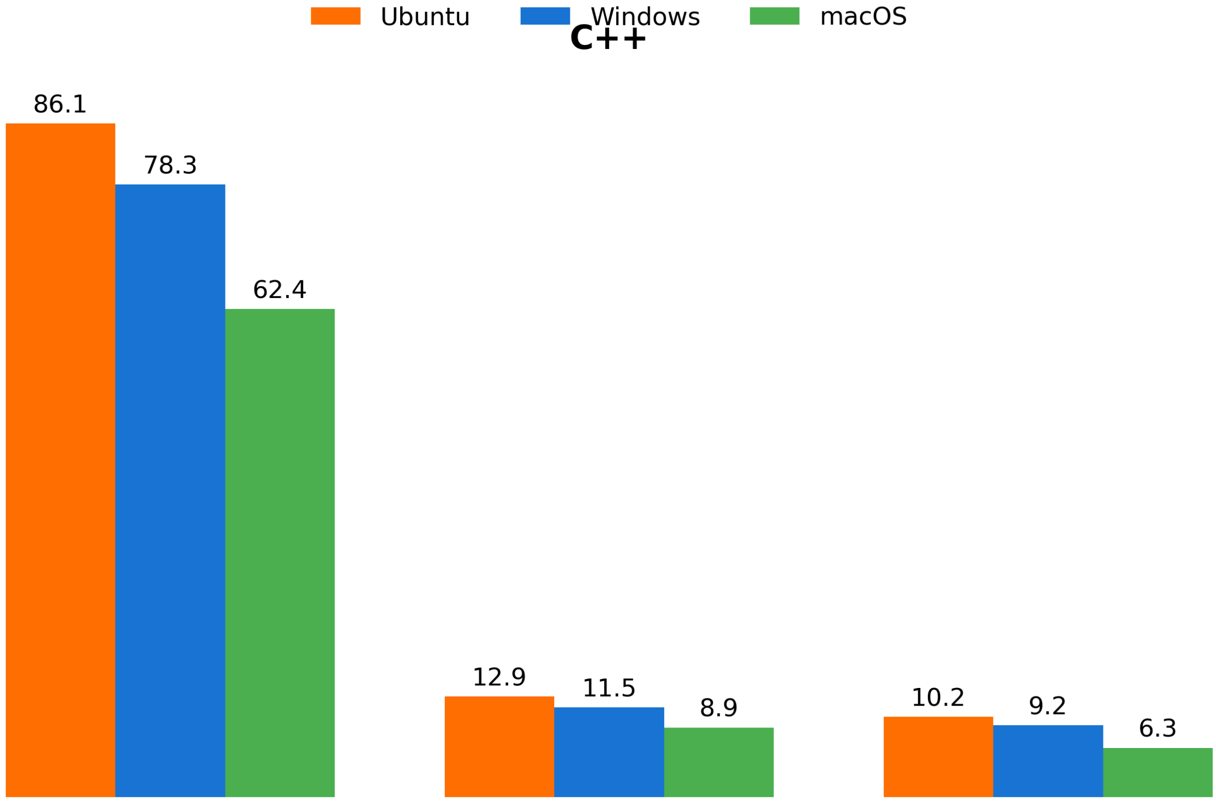
- **Batch insertion** is achieved through **`execute_batch`** and **temporary tables**, combining multiple records into a single batch to reduce database interaction overhead.
- When reading the CSV file, the `dtype` parameter is used to explicitly specify column types (e.g., strings, numeric values), avoiding the performance cost of Pandas' automatic type inference.
- **Thread pool technology** is employed for parallel optimization, significantly improving code execution speed.

C++

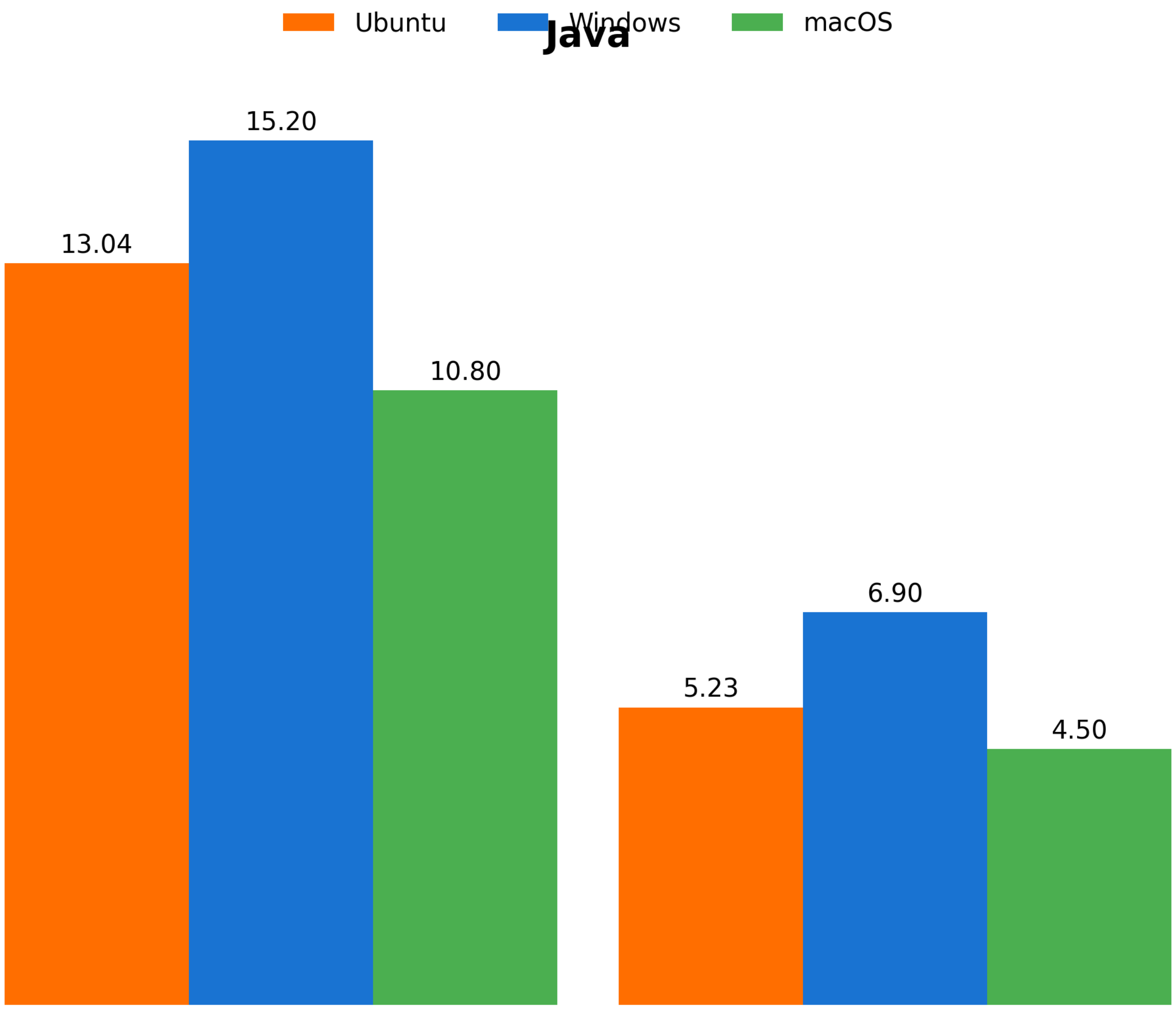
- **Multi-threaded Parallel Insertion**: The script utilizes `std::async` and `std::future` to implement multi-threaded operations. This allows concurrent data insertion into different tables, significantly enhancing the overall data import speed by leveraging the processing power of multiple CPU cores.
- **Batch Streaming Insertion**: Instead of executing individual SQL statements for each row, the script employs `pqxx::stream_to` for batch streaming insertion. This method reduces the number of database round trips, thus improving insertion efficiency and minimizing the load on the database server.
- **Avoiding Data Copying**: To further optimize performance, the script uses pass-by-reference with `std::ref` to avoid unnecessary data copying. This technique helps in reducing memory usage and improves the speed of data transfer between the application and the database.

Compared different scripts in different system

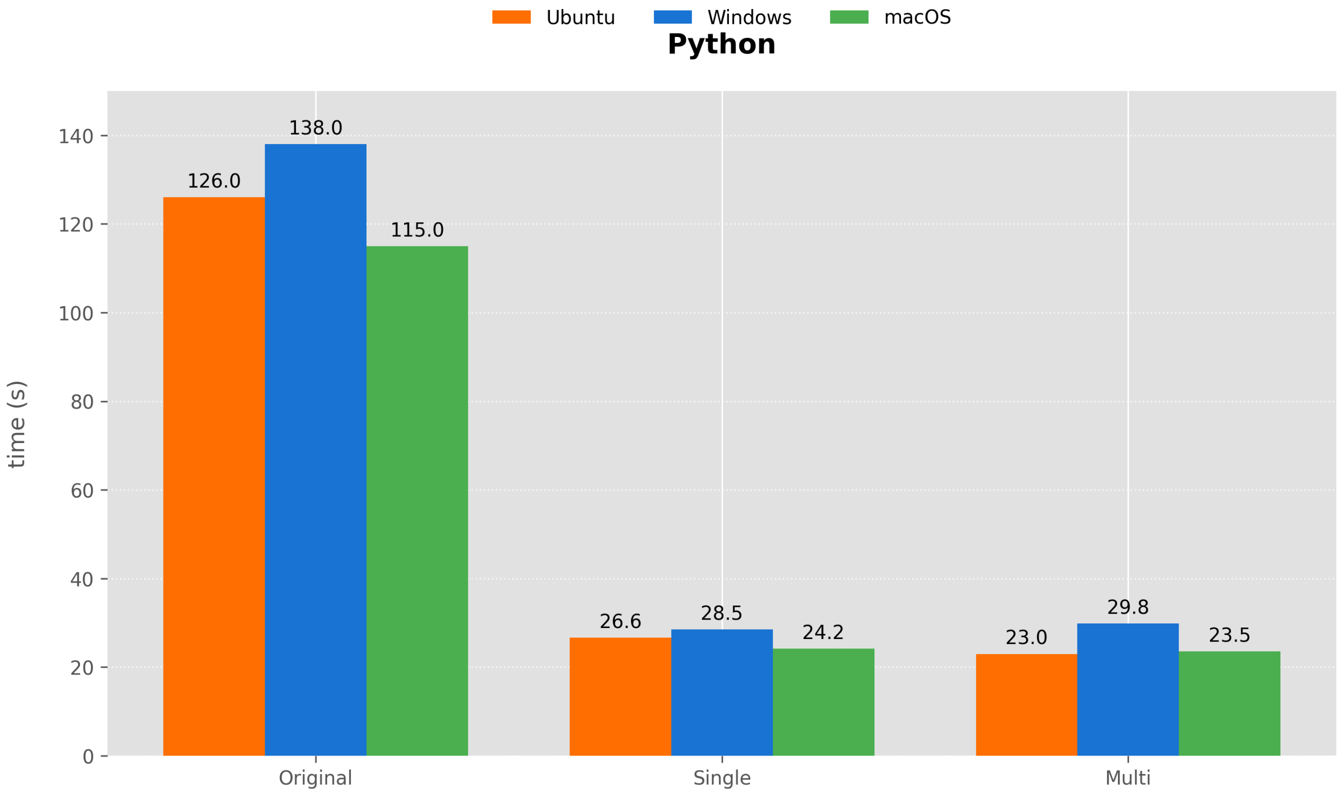
		Ubuntu 22.04	**Windows 11**	**macOS**
Java	single-thread	13.037	15.2	10.8
	multithreading	5.231	6.9	4.5
Python	original version	126.0	138.0	115.0
	single-thread	26.63	28.5	24.2
	multithreading	22.97	29.8	23.5
C++	original version	86.1	78.3	62.4
	single-thread	12.87	11.5	8.9
	multithreading	10.24	9.2	6.3



Overall, the macOS system demonstrates good performance in data import operations across different data scales, while the Ubuntu system performs relatively poorly. The performance of the Windows system falls between the two. This may be related to factors such as the system architecture, memory management, and I/O performance of each operating system.



The chart clearly shows that parallel processing mode significantly outperforms single-thread mode on all operating systems. Among them, macOS demonstrates the best performance in both modes, while Windows has the poorest performance in single-thread mode. The parallel processing mode reduces the execution time by more than half, showing its efficiency in handling large volumes of data.



These charts shows that in general, the Java scripts have the best performance, followed by C++ and then Python.

Multithreading can significantly improve the execution speed of the scripts. For example, in Ubuntu 22.04, the Java multithreading script runs about 2 times faster than the single-threaded version; the C++ multithreading script runs about 1.25 times faster than the single-threaded version.

The main cost of time is connect to the database which make the original scripts run slower than the imporved version.

other databases

In this project, in addition to the originally required PostgreSQL database, we also used the openGauss and MySQL database systems. The purpose of this work is to explore the characteristics and differences of different database systems in terms of data storage, query performance, and data import. By implementing the project on openGauss and MySQL, we gained a deeper understanding of these databases' architectural features, SQL dialect differences. For instance, on openGauss, we explore how to use docker to run the database which can help us use DBMS more conventiently in the future.

Mysql

When migrating to MySQL, the SQL syntax differences from PostgreSQL require modifications to both the table creation scripts and data import logic:

1. Database Schema Adjustments

- **Data Types**:
  - Replace PostgreSQL’s `SERIAL` with MySQL’s `AUTO_INCREMENT`.
  - MySQL implements `BOOLEAN` as `TINYINT(1)`, unlike PostgreSQL’s native `BOOLEAN`.
- **Constraints & Indexes**:
  - MySQL lacks `EXCLUDE` constraints; use `UNIQUE` or application checks.
  - Foreign key actions (`ON DELETE/UPDATE`) must be explicitly defined.

2. Data Import Logic Changes

- **Bulk Insert Optimization**:
  - Replace PostgreSQL’s `COPY` with MySQL’s `LOAD DATA INFILE` or batched `INSERT`.
  - Use `INSERT IGNORE` or `ON DUPLICATE KEY UPDATE` instead of PostgreSQL’s `ON CONFLICT DO NOTHING`.
- **Connection & Transactions**:
  - MySQL defaults to `REPEATABLE READ` isolation (vs. PostgreSQL’s `READ COMMITTED`).

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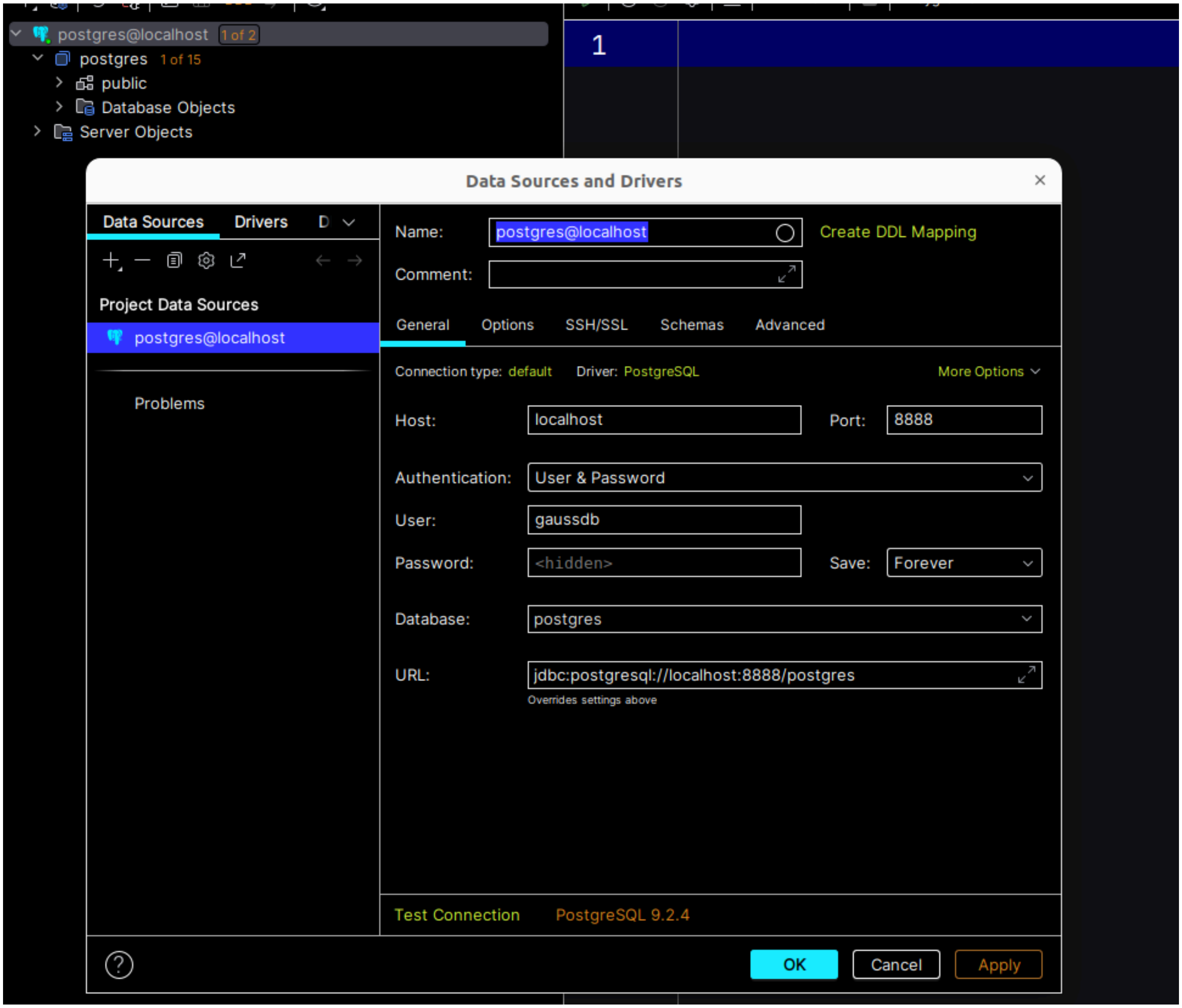
OpenGauss

During the process of using the openGauss database, we found that due to the use of Docker containerization deployment, port mapping is required to enable database management tools like DataGrip to connect and operate the database.

At the same time, although openGauss is a database developed by Huawei based on PostgreSQL, and it is compatible with PostgreSQL in many aspects, there are still differences in some SQL syntax and usage habits. We need to modifying some incompatible SQL statements, adjusting database configuration parameters, and optimizing query performance.

Through this process, we have not only learned how to deploy and manage databases in a containerized environment but also deepened our understanding of the differences between different database systems.



postgres@localhost 1 of 2
postgres 1 of 15
public
Database Objects
Server Objects

Data Sources and Drivers

Name: postgres@localhost

Comment:

Connection type: default Driver: PostgreSQL

Host: localhost Port: 8888

Authentication: User & Password

User: gaussdb

Password: <hidden> Save: Forever

Database: postgres

URL: jdbc:postgresql://localhost:8888/postgres

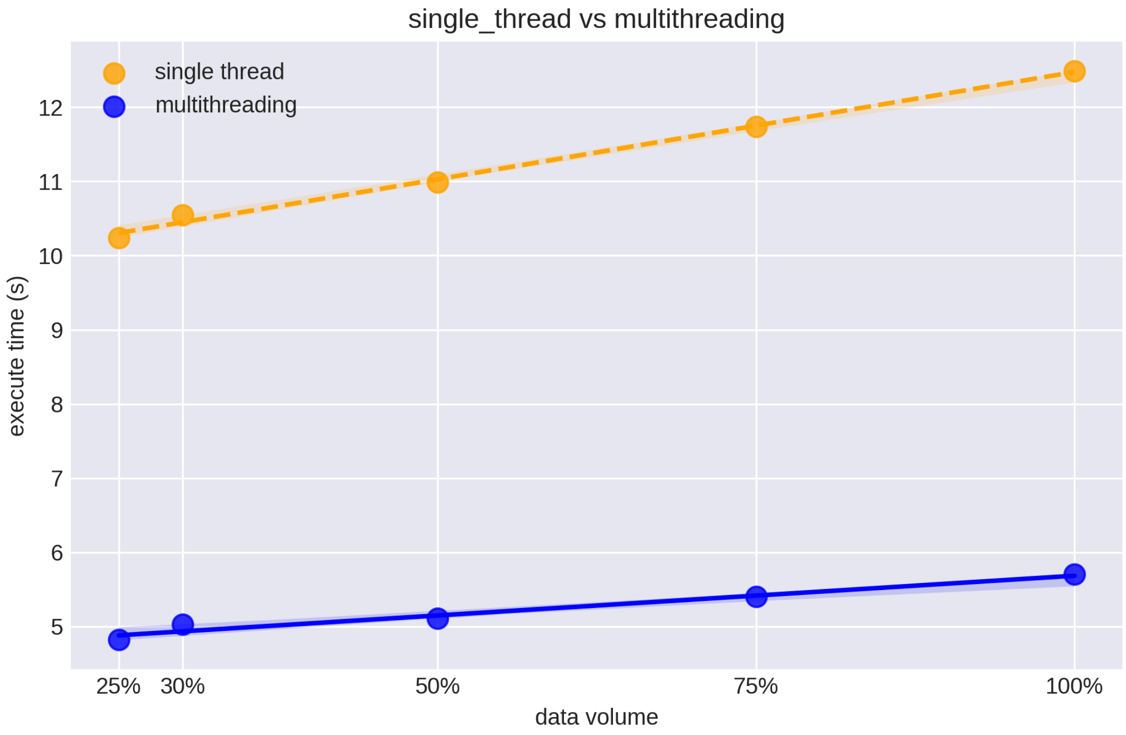
Overrides settings above

Test Connection PostgreSQL 9.2.4

import data with different data volumes

data volume	single-thread time(s)	multithreading time(s)
25%	10.24	4.82
30%	10.55	5.03
50%	10.99	5.11
75%	11.74	5.40
100%	12.49	5.70

In general, multithreading demonstrates high efficiency in data processing tasks. Particularly when dealing with large volumes of data, the advantages of multithreading become more pronounced. Compared to single-threading, multithreading can complete data processing tasks more quickly, thereby enhancing the system's throughput and response speed.



Additionally, it has been observed that the import speed has an approximately linear relationship with the data volume. This implies that as the data volume increases, the import speed also increases correspondingly, but at a relatively stable rate.

In practical applications, we can choose between single-threading and multithreading processing methods based on the amount of data to achieve optimal performance.

Conclusion

In this project, we first established a relational database according to the data information stored in csv files, and then successfully imported the data into it. In the process of import, we further deepen our understanding and application of data import knowledge by comparing the efficiency differences between different import methods. In addition, we analyzed the data in different languages and compared different DBMS, which gave us an insight into different database management system. In the continuous experiment and comparison, our understanding of database index is also deepening.