German University in Cairo
Faculty of Media Engineering and Technology
Database II - CSEN 604

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Project

Course Weight: 20%

Release Date: April 29th , 2022 **Due Date: 11:59PM, June 9th, 2022**

Team Size and Work Plan

- This project is to be done in teams of maximum size 4. Smaller team sizes are acceptable but not more than 4. ***Cross tutorial/major teams are allowed***.
- When you read through the document, you will discover that we have provided many things for you to ensure that you do not waste time doing tasks not related to learning objective of this project. **Your approach should be:**
  1) read this doc
  2) read through all the references in resources section at end of this doc,
  3) modify given Java code to do data insertion,
  4) analyze given queries,
  5) come up with an optimized alternative for each query,
  6) document PostgreSQL output in a report, and
  7) discuss your findings from PostgreSQL output
- Analyzing and writing efficient SQL queries is the focus of this project. That is why, you are given 4 schemas and queries to analyze and rewrite. Most of the work has been done for you. You are given a script to create the schema, a java program which you will modify to populate the data, and you are required to run, analyze and document the performance of the queries (a query is provided and you are asked to come up with alternative one).

Submission

- Your submission should include:
  - A **teams.txt** including your team member names and student ids.
  - A **newqueries.txt** (text) file including your enhanced queries, numbered 1-12.
  - A **PDF report**, including:
    1) Screen capture of output from PostgreSQL analyze for each query.
    2) Details of any special configuration/parameter adjustment you had to make in PostgreSQL to change how it consider plans. This is basically a trace of your work at either the PostgreSQL shell or through pgAdmin.
    3) Discussion of your new query as an alternative to the provided one and why it performs better and which indices should be created for it.
- Your TAs will provide you with details regarding submission means.

Required Software

In this project, you are going to work with "**PostgreSQL**" (http://www.postgresql.org) (version 13 or 14) the most popular open-source SQL database. After downloading and installing PostgreSQL, install the graphical interface **PGAdmin** from https://www.pgadmin.org/download/. You will also need **Eclipse IDE**

Note: last page in this doc is a references page containing pointers to additional resources.

Inputs You Need to Use

You are given four inputs:

1. a shell script **script.sh** which creates 4 different databases and their respective tables.
2. a **README.txt** file about how to run the shell file and the file also has few tips about connecting from Java to PostgreSQL.
3. a java project **MP2DataGenerator** which generates 4 different datasets, one for each database in the shell script and inserts these datasets into their respective tables accordingly.
4. The given queries you need to analyze in a text file **sql-queries.txt**

Executing the shell file

In order to create the databases and tables required for this project, you should execute the shell file using the steps below:

1. Open PostgreSQL shell command
2. Type the following command "PATH-TO-FILE-ON-YOUR-PC/script.sh"
3. Enter your PostgreSQL password

Notes:

- running the script is not mandatory, you can open the file using any text editor and copy and paste the table creation statements in PgAdmin (after connecting to installed PostgreSQL from PgAdmin).

Importing JDBC jar

In order for your java code to work properly, the following steps should be conducted:

1. Import the java project MP2DataGenerator into Eclipse IDE
2. Right Click on the project name, choose build path
3. Click on the add external archives option
4. Browse for "postgresql-jdbc.jar ", which is inside the project folder "MP2DataGenerator"

Note: Make sure to have only one jdbc driver imported. There is already one imported in the project provided to you. You will need to edit the path to that or remove it and add your own. You can do that in Eclipse IDE from Build Path -> Configure Build Path...

PostgresSQL-Java Connection

At this step, all compile errors should be resolved. You will find 4 classes inside the project. Each class generates a data set for each of the 4 databases. For each class do the following:

1. Go to the main method
2. Modify the second and third argument of

```
connection = DriverManager .getConnection (
  " jdbc:postgresql ://hostname:port/dbname" , "username " , "password" ) ;
```

with your postgreSQL username and password.

After applying the steps above, when you run eclipse, a dataset will be generated and inserted in the schema having this class name. For example, running class Schema1 will generate and insert a dataset into schema1 that was created in the postgreSQL server. The process with which the dataset is generated will be explained in the sections below.

Insertion Code

In each schema class, there is a method that is responsible for inserting one tuple for each table in the database. For example, in Schema3 class, there are 3 methods whose name begins with "insert". These three methods insert a single tuple in each of the 3 tables that are in schema3 database. Finally, there is a method named "insert[DatabaseName]" that generates the dataset for this database, by inserting records into its respective tables. For example, in Schema3 class, there is a method named insertSchema3 which generates the dataset of schema3 database.

Dataset Population

Like the insert, in each class there is a method that generates each database's table data. For example, in Schema3 class, there are three methods whose name starts with "populate". Each of these methods, generates data for each table that is in schema3 database.

Schemas & Queries

Following is a description of the 4 schemas used in this project. Each one is a separate schema/database. After each schema, there are one or more SQL statements. In total there are 12 queries you are going to optimize. Your goal will be analyze those queries and try to improve their performance by tuning the database engine and writing a better version of each.

Performance Tuning and Measurement [what is required!]

- After creating each schema, and populating it with specified data, update the database statistics to ensure that PostgreSQL has went through your data and collected all necessary information to do accurate estimation.

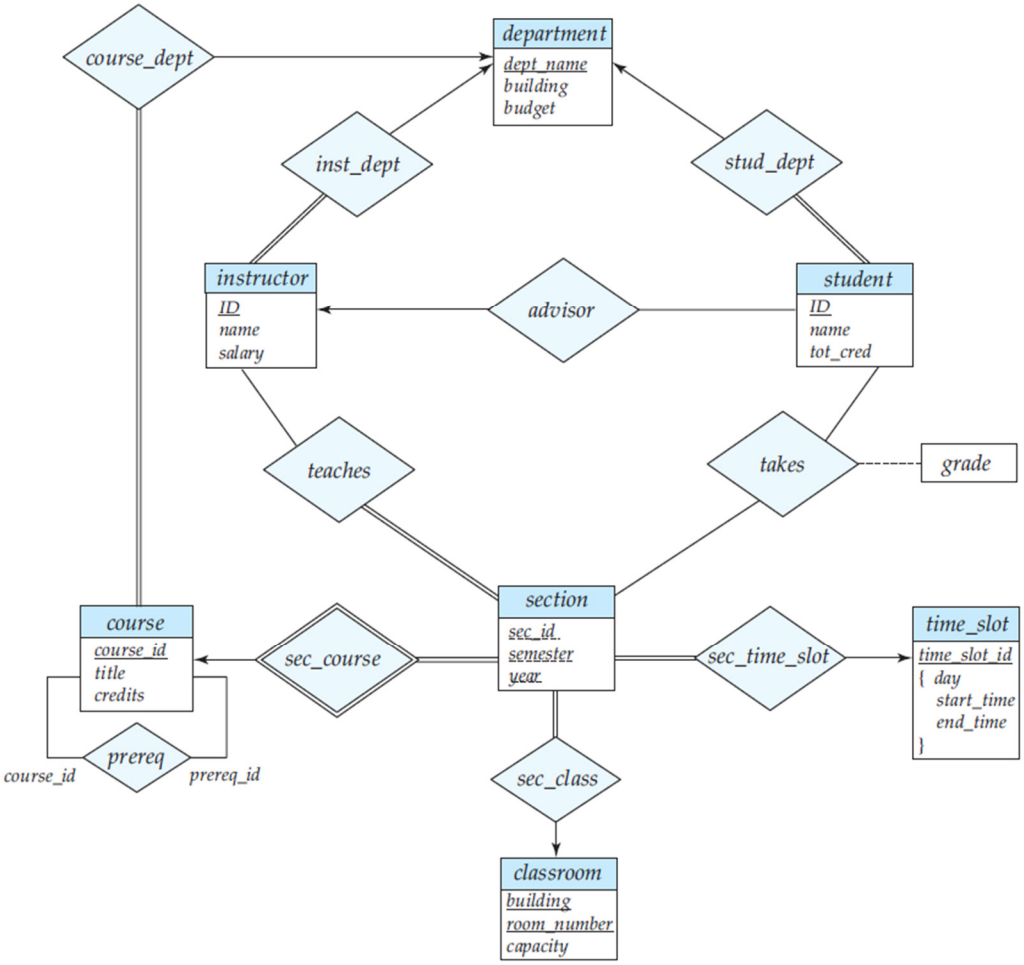
- Next, you need to analyze the execution of the given query (check resources section at end of this document for how to update the statistics and how see the plan for a query). The first time you are going to analyze will be done without the existence of any index. Next, you need to inspect the query, and decide which column or columns, you think if you create an index on, it is going to speed the execution of this query. After creating the index, run analyze again to see what the engine does with the existence of an index. You will do this process 3 times using the following indices which are supported in PostgreSQL: first with B+ Tree indices only, second with Hash based indices only, and third with mixed indices where you use any number/type of indices in PostgreSQL at the same time. Thus, you will report 5 scenarios for the given query:
    1) given query without an index,
    2) given query with B+ trees indices only,
    3) given query with hash indices only,
    4) given query with BRIN indices only,
    5) given query with mixed indices (any mix of your choice).
- Next, you will need to write an alternative query which performs **better** than given query but still produces the same result set. If there is no better query, provide an alternative query which produces the same performance and same result set and **justify clearly why there is no better query.**
- Finally, you will report 5 more scenarios:
    6) your query without an index,
    7) your query with B+ trees indices only,
    8) your query with hash indices only,
    9) your query with BRIN indices only,
    10) your query with mixed indices (any mix of your choice).

The goal behind this exercise is to show you how to discover what plan the query optimizer is using, how to write a more optimized query, and whether (or not) an index makes a difference and which index does enhance performance.

For each of the above scenarios, you need to answer the following question:

What is the execution plan of the query? What is the estimated cost of the plan?

Schema 1



Modifications to Insertion Code:

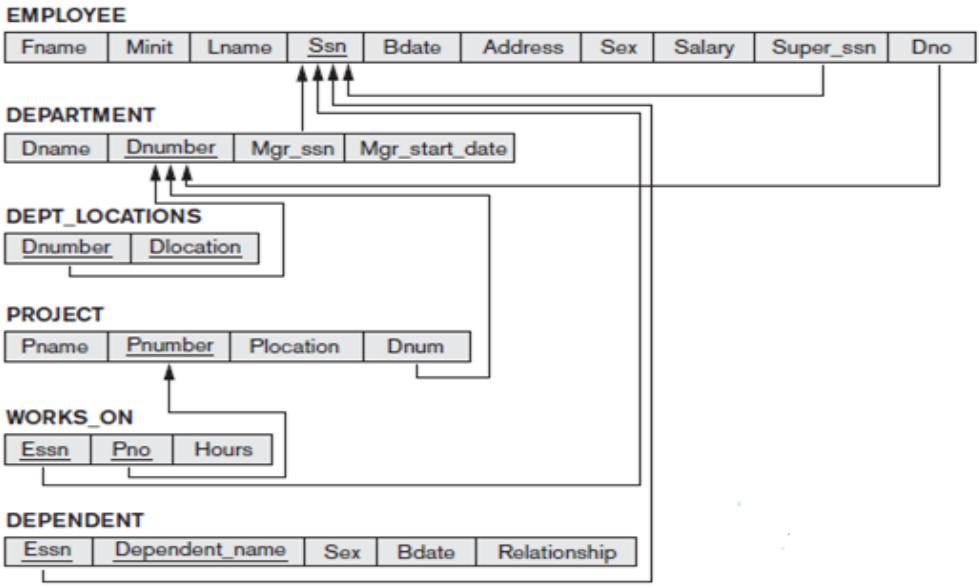
The insertion code provided to you inserts dummy values. You are required to change it to have 60 departments, each offering between 20 and 45 courses. Each department would have between 10 and 35 instructors. Each department would have at least 1100 students. Before inserting the data, check query 1 below you are going to analyze. **The inner result set (semester = 1 and year = 2019) should have 250 rows** at least.

Query 1:

"Display a list of all students in the CSEN department, along with the course sections, if any, that they have taken in Semester 1 2019; all course sections from Spring 2019 must be displayed, even if no student from the CSEN department has taken the course section." This query can be written as:

```sql
select *
from (select *
      from student
      where
      department = 'CSEN') as CS1_student
      full outer join
      (select *
      from takes t inner join section s
                      on t.section_id = s.section_id
      where semester = 1
      and
      year = 2019) as sem1_student
            on CS1_student.id = sem1_student.student_id;
```

Schema 2



Modifications to Insertion Code:

The insertion code provided to you inserts dummy values. You are required to change it to have 16000 employees, 150 departments, 150 department locations, and 9200 projects. Before inserting the data, check queries 2-6 below you are going to analyze, the data that you insert must have values used in those queries. For example, you need to have an employee with name employee1 and department 5 and several who make a salary greater than 40,000. **Each query must return 600 rows in the result set** (an empty result set is not acceptable).

Query 2:

```
select distinct pnumber
from project
where pnumber in
                (select pnumber
                 from project, department d, employee e
                 where e.dno=d.dnumber
                       and
                       d.mgr_snn=ssn
                       and
                       e.lname='employee1' )
               or
               pnumber in
                     (select pno
                      from works_on, employee
                      where essn=ssn and lname='employee1' );
```

Query 3:

Select the names of employees whose salary is greater than the salary of all the employees in department 5

```
select lname, fname
from employee
where salary > all (
      select salary
      from employee
      where dno=5 );
```

Query 4:

Retrieve the name of each employee who has a dependent with the same first name and is the same sex as the employee.

```
select e.fname, e.lname
from employee as e
where e.ssn in (
            select essn
            from dependent as d
            where e.fname = d.dependent_name
            and
            e.sex = d.sex );
```

Query 5:

Retrieve the names of employees who have dependents.

```
select fname, lname
from employee
where exists ( select *
               from dependent
               where ssn=essn );
```

Query 6:

For each department that has more than five employees, retrieve the department number and the number of its employees who are making more than $40,000.

```
select dnumber, count(*)
from department, employee
where dnumber=dno
and
salary > 40000
and
dno =  (
        select dno
        from employee
        group by dno
        having count (*) > 5)
group by dnumber;
```

Schema 3

Sailors(*sid:*integer, *sname:* string, *rating:* integer, *age:* real)

Boats(*bid:*integer, *bname:* string, *color:* string)

Reserves (*sid:* integer, *bid:* integer, *day:* date)

Modifications to Insertion Code:

The insertion code provided to you inserts dummy values. You are required to change it to have 19000 sailors, 3000 boats, and 35000 reserves. Before inserting the data, check queries 7-9 below you are going to analyze, the data that you insert must have values used in those queries Note: in order to see different decisions made internally by the database engine in the query plan and index selection, you must return a non-trivial number of rows in the result set (in the hundreds): an empty result set is not acceptable.

Query 7:

Find the names of sailors who have reserved boat 103.

```
select s.sname
from sailors s
where
s.sid in(  select r.sid
           from reserves r
           where r.bid = 103 );
```

Query 8:

Find the names of sailors 'who ha'ue reserved a red boat.

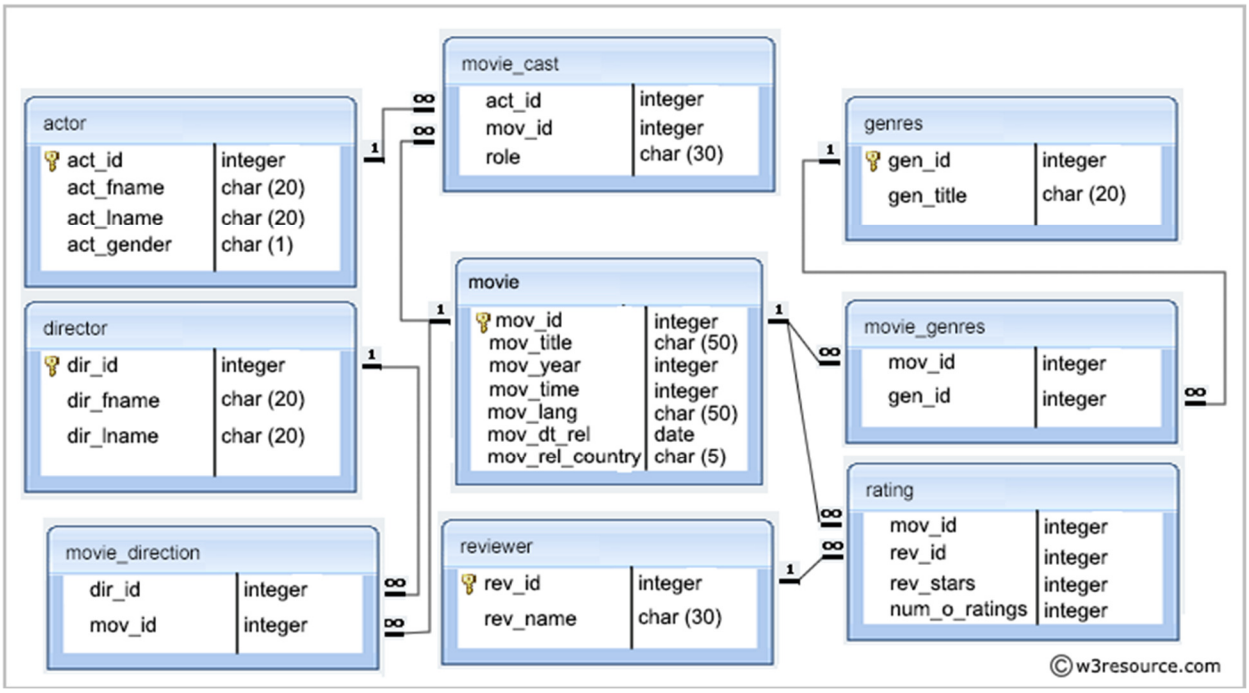
```
select s.sname
from sailors s
where s.sid in ( select r.sid
                 from reserves r
                 where r. bid in (select b.bid
                                  from boat b
                                  where b.color = 'red'));
```

Query 9:

Find the names of sailors who have reserved both a red and a green boat.

```
select s.sname
from sailors s, reserves r, boat b
where
s.sid = r.sid
and
r.bid = b.bid
and
b.color = 'red'
and
s.sid in ( select s2.sid
           from sailors s2, boat b2, reserves r2
           where s2.sid = r2.sid
           and
           r2.bid = b2.bid
           and
           b2.color = 'green');
```

Schema 4



Modifications to Insertion Code:

The insertion code provided to you inserts dummy values. You are required to change it to have 100,000 movies, 120000 actors, and 6000 directors. Before inserting the data, check queries 10-12 below you are going to analyze, the data that you insert must have values used in those queries (an empty result set is not acceptable).

Query 10:

List all the information of the actors who played a role in the movie 'Annie Hall'. **Your result set must have 222 rows.**

```
select *
from actor
where act_id in(
            select act_id
            from movie_cast
            where mov_id in(
                        select mov_id
                        from movie
                        where mov_title ='Annie Hall'));
```

Query 11:

Find the name of the director (first and last names) who directed a movie that casted a role for 'Eyes Wide Shut'. Empty result set not acceptable.

```
select dir_fname, dir_lname
from  director
where dir_id in(
           select dir_id
           from movie_direction
           where mov_id in(
                 select mov_id
                 from movie_cast
                 where role =any( select role
                                  from movie_cast
                                  where mov_id in(
                                             select  mov_id
                                             from movie
                                             where
                                             mov_title='Eyes
                                             Wide Shut'))));
```

Query 12:

Find the titles of all movies directed by the director whose first and last name are Woddy Allen.

Your result set must contain 350 rows.

```
select mov_title
from   movie
where  mov_id in (
                 select mov_id
                 from movie_direction
                 where dir_id=
                       (select dir_id
                       from director
                       where dir_fname='Woddy'
                       and
                       dir_lname='Allen'));
```

Resources

- *Introduction to SQL Queries performance measurement in PostgreSQL*

https://www.citusdata.com/blog/2018/03/06/postgres-planner-and-its-usage-of-statistics/

https://wiki.postgresql.org/wiki/Tuning_Your_PostgreSQL_Server

- *Advanced Tuning*

https://www.postgresql.org/docs/13/static/runtime-config.html

- *Create Statistics*

https://www.postgresql.org/docs/13/sql-createstatistics.html

- *How to use EXPLAIN command and understand its output & other stuff:*

https://www.postgresql.org/docs/13/performance-tips.html

http://www.postgresql.org/docs/13/static/sql-explain.html

- *Creating an Index for a table:*

http://www.postgresql.org/docs/13/static/sql-createindex.html

- *Statistics collected by PostgreSQL:*

https://www.postgresql.org/docs/13/static/planner-stats.html

- *Troublshooting an Index:*

https://www.gojek.io/blog/the-case-s-of-postgres-not-using-index

https://www.pgmustard.com/blog/why-isnt-postgres-using-my-index

- *Writing Efficient SQL:*

https://www.geeksforgeeks.org/12-tips-to-write-efficient-sql-queries/

https://www.stratascratch.com/blog/best-practices-to-write-sql-queries-how-to-structure-your-code/

https://devrajcoder.medium.com/writing-good-and-performant-sql-queries-bec2893d4d93