Automatic Index Creation

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CS349: DataBase and Information Systems
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Indian Institute of Technology Bombay
Spring 2024-25

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Introduction to the Problem Statement

- Indexes are crucial for efficient query execution in relational databases.
- However, developers sometimes forget to create indexes for frequently queried columns.
- This can lead to repeated full relation scans, significantly degrading performance.
- **Goal:** Modify the application layer of PostgreSQL to detect such patterns and automatically create indexes when beneficial.
- Approach:
  - Track full relation scans with equality predicates.
  - Estimate the potential benefit of an index.
  - Automatically trigger index creation if estimated benefit outweighs the cost.
  - Rejecting low selectivity columns, such as gender, which has low number of distinct values.

Directory Structure

Here is the directory structure of the submission:

- `./code`: Contains the header and C++ files for the implementation, along with the Makefile.
- `./theory`: Contains some relevant paper and slides.
- `./documentation`: Contains the report as `readme.pdf`.
- `./README.md`: Contains the instructions to run the code.

About Indices

An index in SQL is a database object that improves the speed of data retrieval operations on a database table.

When a query is executed, the database can use the index to quickly find the relevant rows.

Without an index, the database might need to scan every row to find the data, which is much slower.

When to use indices?

- **Frequent searches on specific columns:** Columns that are often used in WHERE clauses, JOIN conditions or as part of a SELECT query.
- **Large Tables with Heavy Read Operations:** Tables with a vast number of records where read operations are more common than write operations.
- **Columns used in JOINs:** Indexing these columns can speed up the join process.
- **Unique or Primary Key Constraints:** Indices improve lookup efficiency, so easy to impose such constraints.
- **Composite Indices:** When queries often filter on multiple columns, a composite index can be beneficial, rather than creating separate indices for each column.

When to use indices?

There are also cases, where we should refrain from using indices, such as tables with heavy write operations, because indices slow down INSERT, UPDATE, and DELETE operations (index needs to be updated too). Similarly, in case of small tables, or columns with low selectivity (many duplicate values).

Indices, overall lead to improved query performance, slower write opterations, and increased storage requirements.

We can analyze how a query is execueted, and whether an index is effectively used or not by using the `EXPLAIN` command in PostgreSQL. Moreover, to maintain performance, expecially in databases with frequent data modifications, we need to regularly rebuild and reorganize indices.

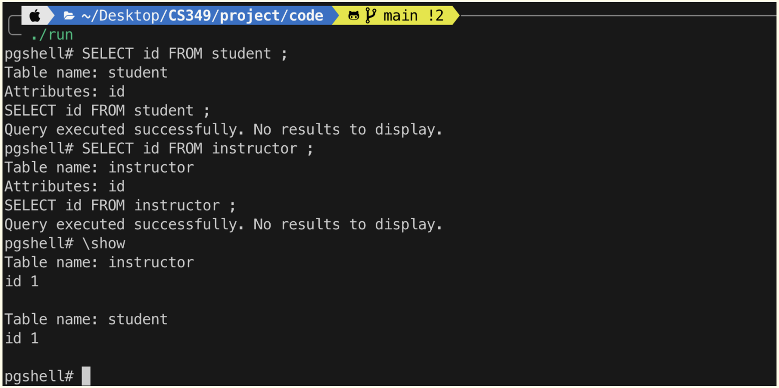
Calculating the frequency of relations and their attributes

For Stage 1 of this project, we made a simple parser, which gives us the list of relations, and the attributes involved in some query. This helps us know the number of times, a particular attribute of a relation is accessed, this in turn can be used to make the decision on whether we should construct an index on that attribute.

For a sample run, the `\show` command can be used to display the frequency results.

Results

Here is the sample output:



```
 ~/Desktop/CS349/project/code   main !2
  ./run
pgshell# SELECT id FROM student ;
Table name: student
Attributes: id
SELECT id FROM student ;
Query executed successfully. No results to display.
pgshell# SELECT id FROM instructor ;
Table name: instructor
Attributes: id
SELECT id FROM instructor ;
Query executed successfully. No results to display.
pgshell# \show
Table name: instructor
id 1

Table name: student
id 1

pgshell# 
```

Figure: Displaying the output of show command

Next Steps

Firstly, we need to create a cost function, which when crosses a threshold, will give us a signal, and an index creation will begin. After this, we need to implement a simple index creation (and removal) policy, such that LRU, MRU, LFU etc. Apart from this, here is the list of papers, which we are planning to read, and will implement the ideas of one of them:

- A tool for automatic index selection in Database Management Systems
- Automatic Index Selection in RDBMS by Exploring Query Execution Plan Space
- Automated Database Indexing Using Model-Free Reinforcement Learning

Thank You