Advanced SQL and the Power of Rewriting Queries

Thank you to all 3 user groups for inviting me and having me be a part of your meetings.

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This presentation is to show in detail one of the many ways to help get a query to run faster. As will be shown there are many factors that can have a impact on query performance, but the one that is very powerful and totally in the hands of the developers is the query rewrite.
Improving SQL performance can be done in one of at least 5 ways. The first 2 ways are totally controlled by the developer. Changing the way a query is written to and keeping the same logic can often times send the optimizer down a different physical path in gathering the rows for the final result set. At times there may be 3, 4, 5, or 6 different ways to write a query and return the same result sets. The SQL must be written in a way that may be processed efficiently by the database. Redesigning program flow, and minimizing the number of time a program sends SQL statements to DB2 can have an impact. An appropriate level of statistics about the data must be gathered to tell the optimizer about the nature of the data being accessed. The way the physical objects are defined must be aligned with the types of queries that are to be performed. The 2 major areas here are indexing and the clustering order of data in a table. Lastly, system tuning may be done to adjust the parameters under which the DB2 subsystem operates to effectively match the workload. Altering system parameters, tuning temporary space, and adjusting buffer pool sizes and thresholds are all examples of this type of tuning. An appropriately tuned system can affect an improvement in performance.

This presentation focuses on the first bullet, changing the SQL.
A review of some of the data in the DB2 sample table DEPT.

<table>
<thead>
<tr>
<th>DEPTNO</th>
<th>DEPTNAME</th>
<th>MGRNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>A00</td>
<td>SPIFFY COMPUTER SERVICE DIV.</td>
<td>000010</td>
</tr>
<tr>
<td>B01</td>
<td>PLANNING</td>
<td>000020</td>
</tr>
<tr>
<td>C01</td>
<td>INFORMATION CENTER</td>
<td>000030</td>
</tr>
<tr>
<td>D01</td>
<td>DEVELOPMENT CENTER</td>
<td>null</td>
</tr>
<tr>
<td>D11</td>
<td>MANUFACTURING SYSTEMS</td>
<td>000060</td>
</tr>
<tr>
<td>D21</td>
<td>ADMINISTRATION SYSTEMS</td>
<td>000070</td>
</tr>
<tr>
<td>E01</td>
<td>SUPPORT SERVICES</td>
<td>000050</td>
</tr>
<tr>
<td>E11</td>
<td>OPERATIONS</td>
<td>000090</td>
</tr>
<tr>
<td>E21</td>
<td>SOFTWARE SUPPORT</td>
<td>000100</td>
</tr>
<tr>
<td>F22</td>
<td>BRANCH OFFICE F2</td>
<td>null</td>
</tr>
<tr>
<td>G22</td>
<td>BRANCH OFFICE G2</td>
<td>null</td>
</tr>
<tr>
<td>H22</td>
<td>BRANCH OFFICE H2</td>
<td>null</td>
</tr>
<tr>
<td>I22</td>
<td>BRANCH OFFICE I2</td>
<td>null</td>
</tr>
<tr>
<td>J22</td>
<td>BRANCH OFFICE J2</td>
<td>null</td>
</tr>
</tbody>
</table>
A review of some of the data in the DB2 sample table EMP.

<table>
<thead>
<tr>
<th>EMPNO</th>
<th>DEPTNO</th>
<th>LASTNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>000010</td>
<td>A00</td>
<td>HAAS</td>
</tr>
<tr>
<td>000020</td>
<td>B01</td>
<td>THOMPSON</td>
</tr>
<tr>
<td>000030</td>
<td>C01</td>
<td>Kwan</td>
</tr>
<tr>
<td>000050</td>
<td>E01</td>
<td>Geyer</td>
</tr>
<tr>
<td>000060</td>
<td>D11</td>
<td>Stern</td>
</tr>
<tr>
<td>000070</td>
<td>D21</td>
<td>Pulaski</td>
</tr>
<tr>
<td>000090</td>
<td>E11</td>
<td>Henderson</td>
</tr>
<tr>
<td>000100</td>
<td>E21</td>
<td>Spenser</td>
</tr>
<tr>
<td>000110</td>
<td>A00</td>
<td>Lucchesi</td>
</tr>
<tr>
<td>000120</td>
<td>A00</td>
<td>O'connell</td>
</tr>
<tr>
<td>000130</td>
<td>C01</td>
<td>Quintana</td>
</tr>
<tr>
<td>000140</td>
<td>C01</td>
<td>Nicholls</td>
</tr>
<tr>
<td>000150</td>
<td>D11</td>
<td>Adamson</td>
</tr>
<tr>
<td>000160</td>
<td>D11</td>
<td>Pianka</td>
</tr>
<tr>
<td>000170</td>
<td>D11</td>
<td>Yoshimura</td>
</tr>
</tbody>
</table>

Partial data
A review of some of the data in the DB2 sample table EMPPROJACT. An employee will have a rows or rows in this table if they are currently working on a project (or projects). They could also have multiple rows if they are working multiple activities within a specific project. There is a 0-many relationship between the EMP table and this EMPPROJACT table.
This request for a report requires 2 tables. There is a 0-many relationship between the tables.
The first thought to fulfill this request would be to code and execute an SQL Join between the 2 tables, zeroing in on the employees that are a part of Project = ‘IF2000’.

As can be seen, when a join is coded (and knowing the relationship between the tables) there is a potential for duplicates that show up due to the multiple activities some employees can be assigned for that project. This is where developers need to be aware and know the relationship between tables. I have seen many incident reports come about in production where a query was running for awhile and working only because it was lucky that there existed no duplicate in the data. But when more data was added, duplicates came about and the program/query then issued duplicate rows.

KNOW YOUR DATA and RELATIONSHIPS.

What can be done to eliminate the duplicates?
The easiest and first thought most developers think of is to add the Distinct word as part of the select, which will eliminate the duplicates.

In order for the RDBMS to eliminate duplicates via the Distinct, it may load the data into a Sort Workfile and execute a sort in order to get the data ordered. It then pulls out the unique values. Distinct does not always cause a sort to take place as DB2 often does sort avoidance. The only way to know for sure would be executing a DB2 Explain.

If there is a sort specific to the distinct, there is some overhead involved in this sort. A workfile must be allocated, then loaded, then sorted, and from there unique values are pulled for the final result set. Sorts are pretty fast in DB2, and my first questions when I see a sort occurring are: Can it be eliminated? How big is the sort? Sorts are expensive as their size.

Group By will also eliminate duplicates and works the same as a distinct.
There are other ways to eliminate the duplicates needed for this example, both ways requiring a Subquery. These options are available because the there is no data needed to be retrieved from the EMPPROJACT table. This give us the option to take it out of the join, and move it into a subquery.

The first way is to code a Non Correlated Subquery, as shown on this page.

This query is checking to see if each EMPNO value is in the list of EMPNOs generated by the subquery. An EMPNO could be in the list multiple times, but the results will not show the EMPNO multiple times. Remember that the list of values coming out of a non-correlated subquery will have its results sorted in order to eliminate duplicates in the list, and to get the list in ascending order.

Db2 will sometimes take the values from the non correlated subquery, and instead of keeping the list in a an In-List, will put the values into a temporary table and then use it in a join to the outer table.
The other way to eliminate duplicates is by coding the SQL using a Correlated Subquery with the Exists clause.

The logic here is as each EMPNO value is passed to the subquery for execution, the question “Does that join condition exist for the particular EMPNO value?” is processed. Even if it exists multiple times in the subquery, the value will still only get written out once.

Writing it this way eliminates any sorts that could be taking place in a jpin, but the subquery will get executed multiple times.

Which way is best?
1). Using the Distinct
2). Writing a subquery using the ‘In’
3). Writing a subquery using the ‘Exists’

Of course the answer is ‘It depends’.
This is pretty common logic for developers and analyst because it makes a little more straightforward sense. But this query is the most expensive in execution time and CPU. This is due to the fact that it must first count up all the rows that meet the criteria for each specific employee number, instead of stopping at the first occurrence (in the case of EXIST logic) or the one time building of an IN list. There is no need to always count the number of rows for each employee number working on 'IF20000' and comparing to 0. The counting of rows at times can have considerable overhead involved. This logic seems to be found in much older code at companies and should be rewritten whenever found.
This screen sums up 3 different processes to eliminate duplicates for the example given. Which one is best? It depends:

How big is the Distinct sort? The larger the size of sorts the more expensive the query and runtime. This is typically the worst. What does the join process look like? Are there indexes involved in the join? Which join method? Any join sorts?

Non Correlated Subquery. This is typically better because the sort is smaller than the Distinct sort. The sort is done on only one column for however many values come out of the subquery.

Correlated Subquery. This subquery will execute multiple times so it is imperative that the subquery uses a index when it gets processed for each value sent to it via the join. If the subquery can execute as ‘Index Only’ and there is matching index occurring, executing many times can be very fast and efficient.

So the answer is ‘It Depends’. The nice thing about these is that we have options for duplicate data at times and they all execute very different within DB2. Depending on the data and physical design, one will usually run better than the others.
This screen sums up 3 different processes to eliminate duplicates for the example given. Which one is best? It depends:

As can be seen by the different costings, proves there are different optimizations going on.
This screen starts the second example. This is a typical table design where an ID / ACCT_NUM may have multiple rows each unique based on an ACCT type, status, code, ....

This table is not one of the DB2 sample tables but a good example of a common design. In this example, how do we find the employee numbers that have both a row with value of ‘MAT’ in the MAJOR column, and also a row with a value of ‘CSI’ in the MAJOR column?
The first solution would be to code a query with a Group BY and Having clause to see which EMPNO(s) have both (a count of 2) rows that have a ‘MAT’ and ‘CSI’.
The next solution would be to code what’s called a ‘Quota Query’ where the number 2 is used in a correlated subquery.
PROBLEM: Find all employees who major in math (MAT) and computer science (CSI).

<table>
<thead>
<tr>
<th>EMPNO</th>
<th>MAJOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>MAT</td>
</tr>
<tr>
<td>E2</td>
<td>MAT</td>
</tr>
<tr>
<td>E3</td>
<td>CSI</td>
</tr>
<tr>
<td>E4</td>
<td>ENG</td>
</tr>
</tbody>
</table>

Self Join Logic:

```sql
SELECT EMPNO
FROM EMPMAJOR AS EMP1 JOIN
     EMPMAJOR AS EMP2
ON EMP1.EMPNO = EMP2.EMPNO
WHERE EMP1.MAJOR = 'MAT'
AND EMP2.MAJOR = 'CSI';
```

And the last way to code logic for this would be using an SQL ‘Self Join’ where you join the EMP table to itself by EMPNO. And by joining this way we code where in one table there is a row with ‘MAT’ and self joining back but looking for a ‘CSI’ row.
Example 3 – Solution 1

**PROBLEM:** Find the youngest employee in each department.

**HINT:** Youngest employee would be the one with highest birthdate

```
SELECT E1.EMPNO, E1.LASTNAME
FROM EMP AS E1
WHERE E1.BIRTHDATE = (SELECT MAX(E2.BIRTHDATE)
                        FROM EMP E2
                        WHERE E2.DEPTNO = E1.DEPTNO)
```

This screen starts the third example. Each employee row in the EMP table contains the department that the employee works in and their birth date. This query is to find the youngest employee in each department.

Solution 1 would be coding a query with a correlated subquery.
Example 3 – Solution 2

PROBLEM: Find the youngest employee in each department.

```
SELECT E1.EMFNO, E1.LASTNAME
FROM EMP E1
WHERE (E1.DEPTNO, E1.BIRTHDATE) IN
      (SELECT E2.DEPTNO,
         MAX(E2.BIRTHDATE)
      FROM EMP E2
      GROUP BY E2.DEPTNO)
```

This solution is using what is called a Row-Value expression in SQL where the ‘IN’ predicate contains 2 values for each entry in the in list.

The in-list would look like (deptno1 and max birthdate, deptno2 and max birthdate, ...)
Example 3 – Solution 3

PROBLEM: Find the youngest employee in each department.

WITH X AS
(SELECT DEPTNO,
 MAX(BIRTHDATE) AS MAX_BIRTHDATE
 FROM EMP
 GROUP BY DEPTNO)
SELECT E.EMPNO, E.LASTNAME, E.BIRTHDATE
 FROM EMP E, X
 WHERE E.BIRTHDATE = X.MAX_BIRTHDATE
 AND E.DEPTNO = X.DEPTNO
 ORDER BY E.EMPNO
;

This solution is using what is called a Row-Value expression in SQL where the ‘IN’ predicate contains 2 values for each entry in the in list.

The in-list would look like (deptno1 and max birthdate, deptno2 and max birthdate, ...)

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Optimizer Costing

This screen shows DB2 estimated optimizer costing from the DB2 Explain for the previous 2 queries. DB2 thinks that the Row-Value solution 2 would be the better query.

The main point here is the difference in costing shows that the optimizer is doing different processing in getting the same result set. Remember that the costing numbers from the DSN_STATEMENT_TABLE are guestimates from DB2, and not actual runtime cost. Testing would show actuals.
Example 4 – Solution 1

List all departments where a department average bonus is greater than its department average salary.

```
SELECT D.DEPTNAME, D.LOCATION
FROM DEPT D
WHERE (SELECT AVG(BONUS) FROM EMP E1
       WHERE D.DEPTNO = E1.DEPTNO)
       > (SELECT AVG(SALARY) FROM EMP E2
       WHERE D.DEPTNO = E2.DEPTNO)
```

Example 4 needs some aggregation (average bonus and average salary) calculations for its logic. This first solution is by coding correlated subqueries that are scalar fullselects to compare.
Example 4 – Solution 2

List all departments where a department average bonus is greater than its department average salary.

```
SELECT D.DEPTNO, D.LOCATION, AVG(BONUS), AVG(SALARY)
FROM THEMIS81.DEPT AS D
INNER JOIN
    THEMIS81.EMP AS E1 ON D.DEPTNO = E1.DEPTNO
GROUP BY D.DEPTNO, D.LOCATION
HAVING AVG(E1.BONUS) >
   (SELECT AVG(SALARY)
    FROM THEMIS81.EMP E2
    WHERE E2.DEPTNO = D.DEPTNO)
```

This solution uses the Group By and Having SQL logic to obtain the results. Notice that the Having clause can also be correlated. This solution allows to also have the aggregated amounts as part of the output.
Example 4 – Solution 3

List all departments where a department average bonus is greater than its department average salary.

WITH X AS
   (SELECT DEPTNO, AVG(BONUS) AS AVG_BONUS,
    AVG(SALARY) AS AVG_SALARY
    FROM EMP
    GROUP BY DEPTNO)
SELECT D.DEPTNO, D.DEPTNAME, X.AVG_BONUS, X.AVG_SALARY
FROM DEPT D, X
WHERE X.AVG_BONUS > X.AVG_SALARY
AND X.DEPTNO = D.DEPTNO

Solution 3 uses a Common Table Expression (CTE) where the averages are calculated ahead of time and materialized into a temp table that can be used in a direct join to the DEPT table. This solution allows to also have the aggregated amounts as part of the output.

These are great example of result sets that need both detail data from a table along with aggregated data in each line.
This is an example of the DB2 Explain output for the access paths chosen for each of the previous 3 queries. Notice each one is very different than the others.

Notice the ‘X’ table. This is the CTE name given in solution 3. By seeing this table name in the DB2 Explain output tells us that the table will be materialized.
This is the guesstimated runtime costs for the previous 3 queries. Notice big differences in costing numbers.
This is very typical programming logic for any relational database where you need to know the rows in 1 table where the primary key id not in another table: 3 ways to do this (NOT IN, NOT EXISTS, ANTI JOIN).

This is an example of the ‘NOT IN’ logic.

Example 5 – Solution 1

List employees that are not working on projects. This would be those EMP rows that do not have EMPNO values in the EMPPROJACT table.

SELECT E.EMPNO, E.LASTNAME
FROM EMP E
WHERE E.EMPNO NOT IN
(SELECT EPA.EMPNO
FROM EMPPROJACT EPA)
Example 5 – Solution 2

List employees that are not working on projects. This would be those EMP rows that do not have EMPNO values in the EMPPROJACT table.

SELECT E.EMPNO, E.LASTNAME
FROM EMP E
WHERE NOT EXISTS
  (SELECT 1
   FROM EMPPROJACT EPA
   WHERE EPA.EMPNO = E.EMPNO)

Solution 2 shows the ‘NOT EXISTS’ correlated subquery way to code for the results.
Example 5 – Solution 3

List employees that are not working on projects. This would be those EMP rows that do not have EMPNO values in the EMPPROJACT table.

```
SELECT E.EMPNO, E.LASTNAME
FROM EMP E
LEFT JOIN
    EMPPROJACT EPA ON EPA.EMPNO = E.EMPNO
WHERE EPA.EMPNO IS NULL
```

Solution 3 is called the ‘ANTI JOIN’ where you code up an outer join, and then ask for the rows from the null supplying table where the joined column in null. This specifies that a particular join key was not found on the other table.
Again, looking at the DB2 Explain access paths for the previous 3 queries shows very different access paths.
Optimizer Costing

```
SELECT QUERYNO, COST_CATEGORY, PROCMS, PROCSU, REASON
FROM DSN_STATEMENT_TABLE
ORDER BY QUERYNO
WITH UR
;
```

<table>
<thead>
<tr>
<th>QUERYNO</th>
<th>COST_CATEGORY</th>
<th>PROCMS</th>
<th>PROCSU</th>
<th>REASON</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>25661500</td>
<td>25035600</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>24642</td>
<td>24041</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>18325</td>
<td>17878</td>
<td></td>
</tr>
</tbody>
</table>

And with different access paths comes different costing numbers.
Another very common programming task with tables that contain multiple rows with the same key value, but are different based on a timestamp column.
Programming logic typically wants us to get the most current row (Max Timestamp column). This screen 2 different ways to code for this.
Works well with multiple join fields, or max number of other fields, or getting the min instead too... If you have a possibility of multiple max dates or timestamps containing same values, you can use a second field to narrow it down in the AND clause.
For example: Table EMP2 contains duplicate rows with an UPD_TSP column.

```sql
SELECT EMPNO, UPD_TSP
FROM EMP2 T1
WHERE T1.EMPNO = '000010'
AND T1.UPD_TSP =
   (SELECT MAX(T2.UPD_TSP)
    FROM EMP2 T2
    WHERE T2.EMPNO = T1.EMPNO)
;

SELECT T1.EMPNO, T1.UPD_TSP
FROM EMP2 T1 LEFT JOIN
     EMP2 T2 ON T1.UPD_TSP < T2.UPD_TSP
     AND T1.EMPNO = T2.EMPNO
WHERE T1.EMPNO = '000010'
   AND T2.UPD_TSP IS NULL
;```
Example 7 is a little involved and is an area in SQL programming called ‘Relational Divide’ logic. This can be troublesome when the ‘All Activities’ change from day to day, week to week, etc. So the query cannot really hard code the values.

In this example, the activities between 90 and 110 are currently 3 activities (90, 100, 110).
The first solution in using a Group By with Having logic. In this solution the having logic needs to know the number of distinct activities each EMPNO has (between 90 and 110) and compare that to the actual number of activities there could be between 90 and 110.

```
SELECT EPA.EMPNO
FROM EMPPROJECT EPA
WHERE EPA.ACTNO BETWEEN 90 AND 110
GROUP BY EPA.EMPNO
HAVING COUNT(DISTINCT ACTNO) =
    (SELECT COUNT(*)
     FROM ACT A
     WHERE A.ACTNO BETWEEN 90 AND 110)
```

The number of activities this person works

...is equal to the number of activities

EMPNO
000140
Solution2: The 2 “NOT EXISTS” correspond to the double negative derived earlier and give rise to the name double double (or double negative) for the general class of solutions using this approach.

The search of all employees is the outermost level (E level). Since the E level is dependent on a NOT EXIST, an employee will go to the result if the search at the next level (A level) is empty. The search at the A level will be empty if the search at the EPA level (also a NOT EXISTS predicate) always finds a match.

The EPA level always returns exactly 1 row (if the employee at the E level works on an activity at the A level) or will be empty (if the employee at the E level does not work the activity at the A level).

A non match at the EPA level returns TRUE to the A level which immediately returns FALSE to the E level rejecting that employee.
Solution 3 shows ‘NOT EXISTS’ with the EXCEPT keyword (again an double negative).
“I have noticed that when the developers get educated, good SQL programming standards are in place, and program walkthroughs are executed correctly, incident reporting stays low, CPU costs do not get out of control, and most performance issues are found before promoting code to production.”

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Thank you for allowing me to share some of my experience and knowledge today!

Tony Andrews
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• I hope that you learned something new today
• I hope that you are a little more inspired when it comes to SQL coding and performance tuning

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