CS 764: Topics in Database Management Systems
Lecture 5: Query Optimization-2

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9/21/2020

Announcements

To ask a question in-class

- Raise your hand
- With the instructor’s permission, ask in the order of hand raising

Switch to Zoom?

- Lecture recordings will be uploaded to uwmadison.app.box.com

Discussion Highlights

EMP

ENAME	DNAME

TCARD = 100 # data pages
NCARD = TCARD * 100 # tuples
DEPT.IDX_ENAME (clustered)
DEPT.IDX_DNAME (non-clustered)

```
SELECT    ENAME
FROM      EMP
WHERE     DNAME = 'CS";
```

Q1: What are the possible access paths on EMP?

1. Segment scan
2. Clustered index scan on ENAME
3. Non-clustered index scan on DNAME

Discussion Highlights

EMP

ENAME	DNAME

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DEPT.IDX_DNAME (non-clustered)

```
SELECT    ENAME
FROM      EMP
WHERE     DNAME = ‘CS”;
```

Q2: Assume selectivity factor F = 1/10 for predicate DNAME=‘CS’, which access path should be picked for the query above?

Segment scan cost = **100 / P**

ENAME index scan cost = **NINDEX(I) + 100**

DNAME index scan cost = **(NINDEX(I)+10000) / 10**

(Assuming no caching in buffer pool)

Note: NINDEX(I) ≠ 1~3

Today’s Paper: Query Optimization-2

An Overview of Query Optimization in Relational Systems

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1. OBJECTIVE

There has been extensive work in query optimization since the early ‘70s. It is hard to capture the breadth and depth of this large body of work in a short article. Therefore, I have decided to focus primarily on the optimization of SQL queries in relational database systems and present my biased and incomplete view of this field. The goal of this article is not to be comprehensive, but rather to explain the foundations and present samplings of significant work in this area. I would like to apologize to the many contributors in this area whose work I have failed to explicitly acknowledge due to oversight or lack of space. I take the liberty of trading technical precision for ease of presentation.

2. INTRODUCTION

Relational query languages provide a high-level “declarative” interface to access data stored in relational databases. Over time, SQL [41] has emerged as the standard for relational query languages. Two key components of the query evaluation component of a SQL database system are the *query optimizer* and the *query execution engine.*

The query execution engine implements a set of *physical operators*. An operator takes as input one or more data streams and produces an output data stream. Examples of physical

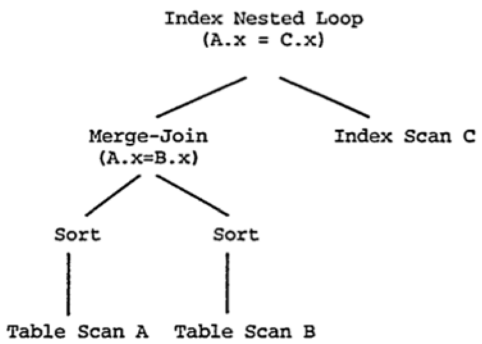


Figure 1. Operator Tree

The query optimizer is responsible for generating the input for the execution engine. It takes a parsed representation of a SQL query as input and is responsible for generating an *efficient* execution plan for the given SQL query from the space of possible execution plans. The task of an optimizer is nontrivial since for a given SQL query, there can be a large number of possible operator trees:

PODS 1998

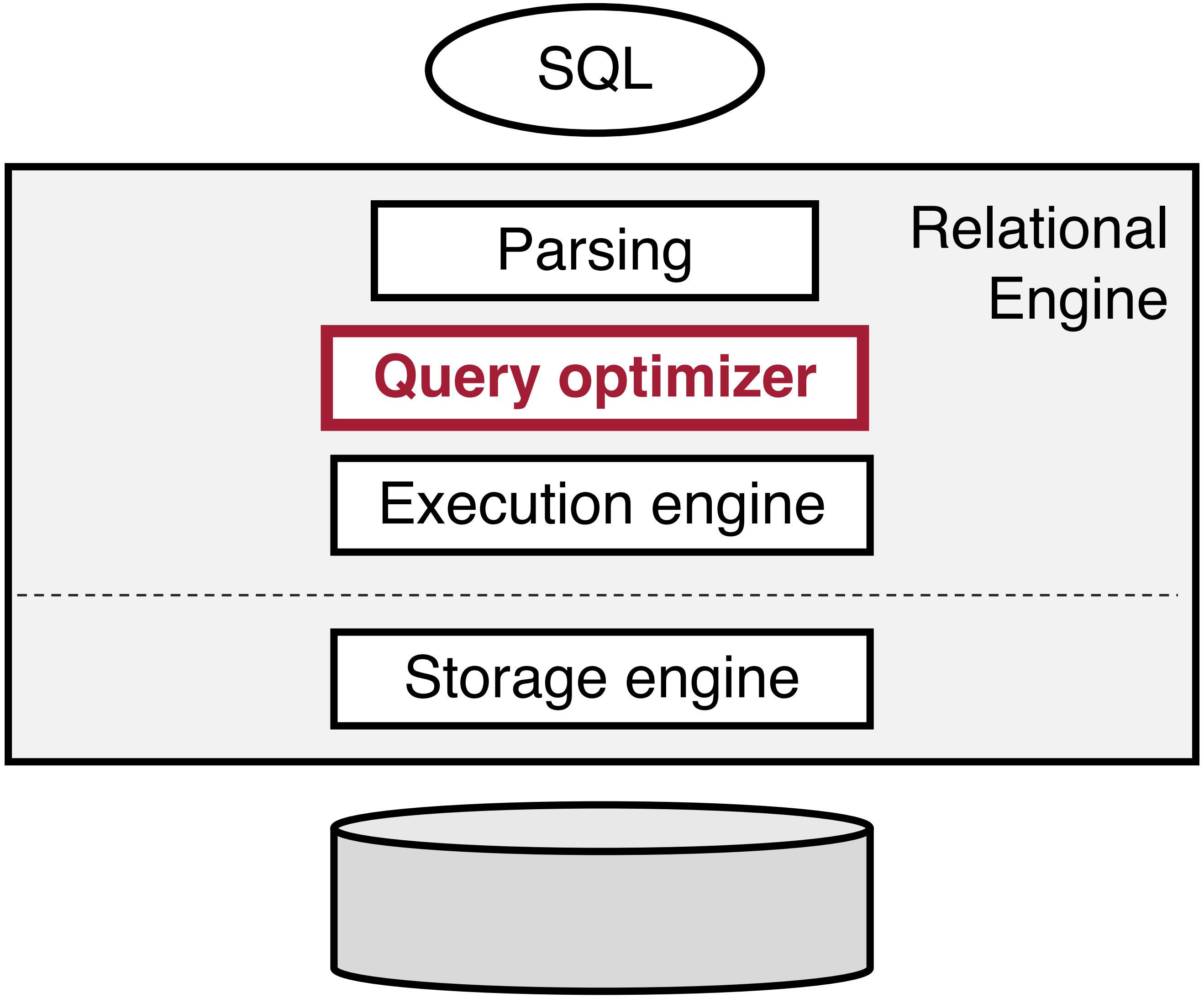
Agenda

Query optimization components

- Search Space
- Cost estimation
- Enumeration algorithm

Other considerations

Query optimization components



Query optimization components

Search space includes plans that have low cost

Cost estimation is accurate

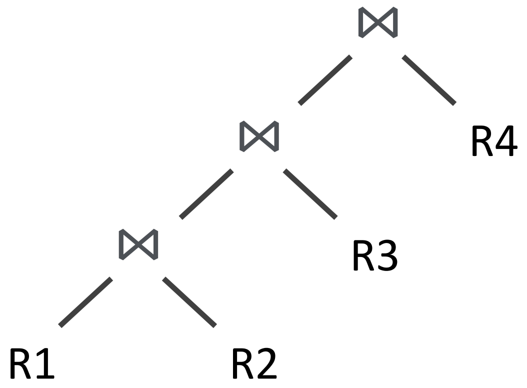
Enumeration algorithm is efficient

Search Space

Search space of System R

- Linear sequence of joins
- Avoiding Cartesian products
- No discussion of outerjoins
- No discussion of group by
- No discussion of multi-block queries

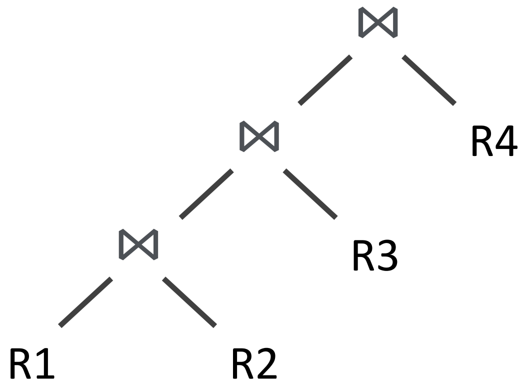
Search Space – Join Order



left-deep tree

Convention: right child is the inner relation

Search Space – Join Order



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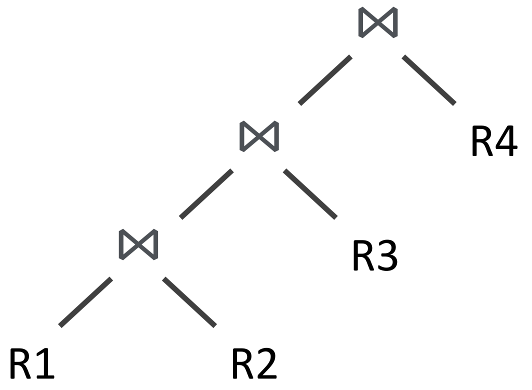
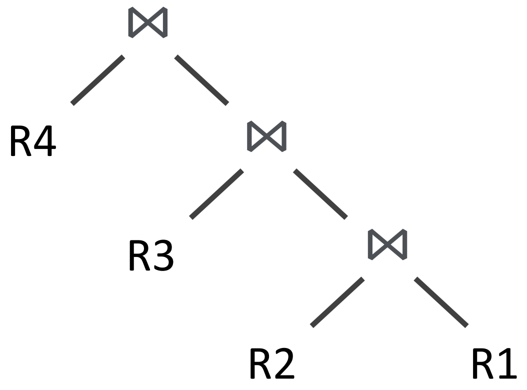
Convention: right child is the inner relation

For nested-loop join or hash join, a left-deep tree allows tuples to be passed through pipelining

Search Space – Join Order



left-deep tree

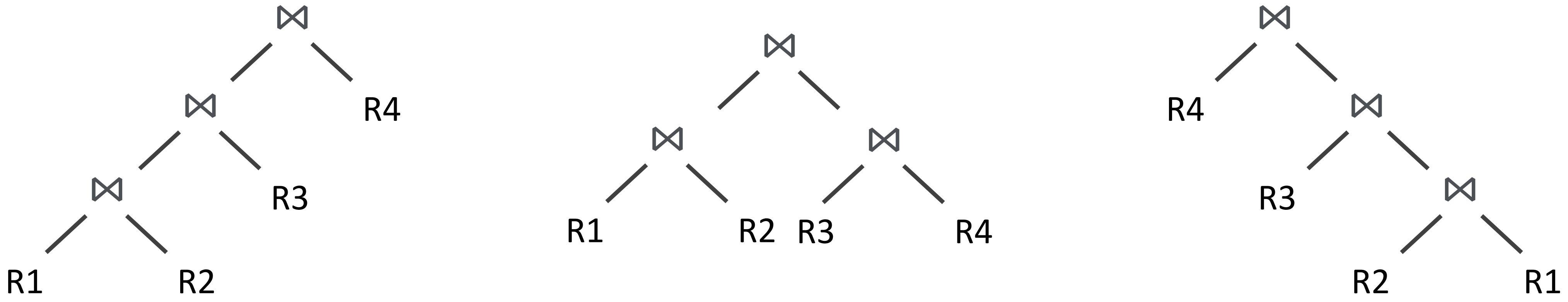


right-deep tree

Convention: right child is the inner relation

For nested-loop join or hash join, a left-deep tree allows tuples to be passed through pipelining

Search Space – Join Order



left-deep tree bushy tree right-deep tree

Convention: right child is the inner relation

For nested-loop join or hash join, a left-deep tree allows tuples to be passed through pipelining

Bushy tree may produce cheaper plans but are rarely considered due to the explosion of search space

Search Space – Cartesian Product

System R defers Cartesian products after all the joins

Evaluating Cartesian products early sometimes leads to cheaper plans

- Example: dimension tables in OLAP in a **star schema**

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- Example: dimension tables in OLAP in a **star schema**

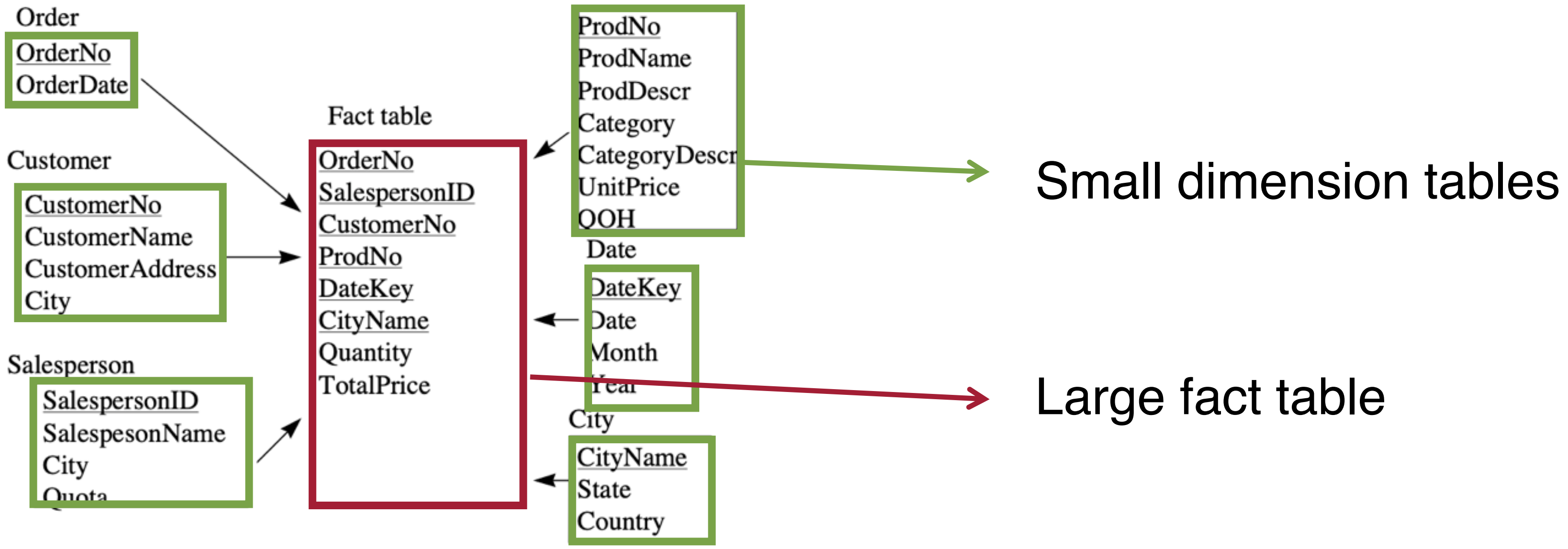


Figure 3. A Star Schema.

* Figure from *"An Overview of Data Warehousing and OLAP Technology"*

Search Space – Outer Join

One-sided outer joins are asymmetric and do not commute

- Join(R, S LOJ T) = Join(R, S) LOJ T

Repeatedly apply this rule to move outer joins after regular joins; regular joins can be freely reordered among themselves

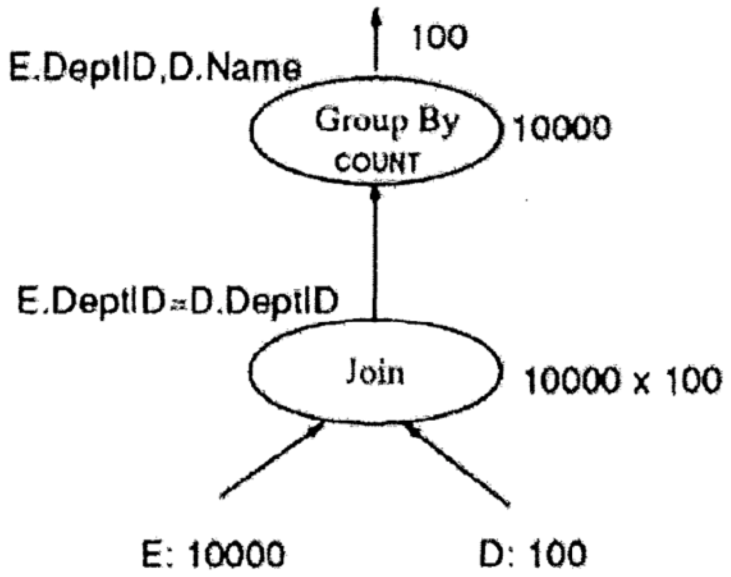
Search Space – Group By

Example:

SELECT D.name, count(*)
FROM EMP as E, DEPT as D
WHERE E.DeptID = D.DeptID
GROUP BY D.name

E has 10000 tuples

D has 100 tuples



Plan 1: Group by after join

Search Space – Group By

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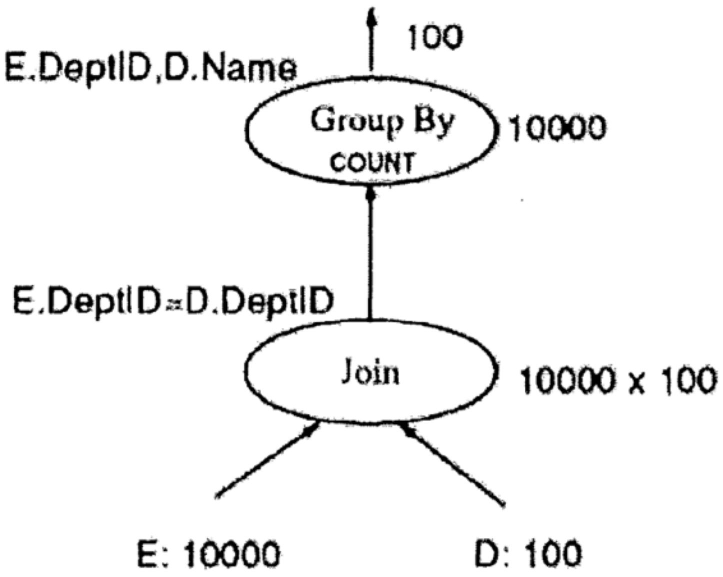
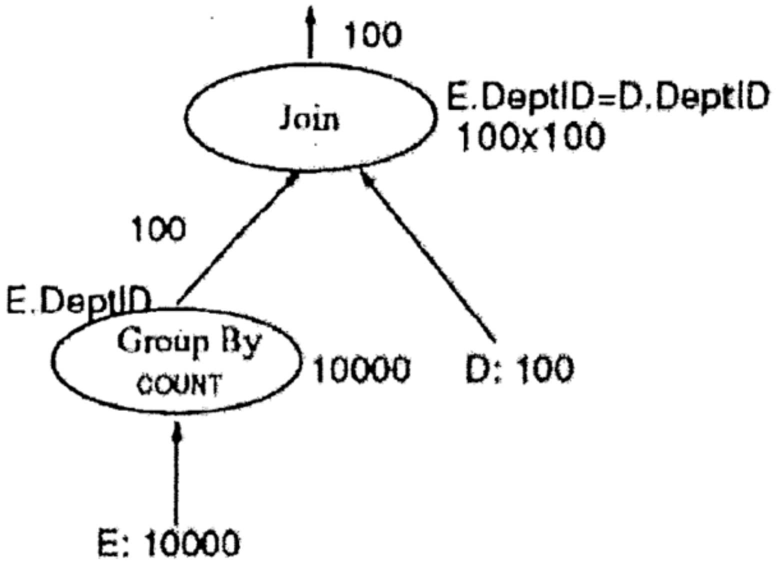


Plan 1: Group by after join



Plan 2: Group by before join

Search Space – Group By

Example:

SELECT D.name, count(*)
FROM EMP as E, DEPT as D
WHERE E.DeptID = D.DeptID
GROUP BY D.name

E has 10000 tuples

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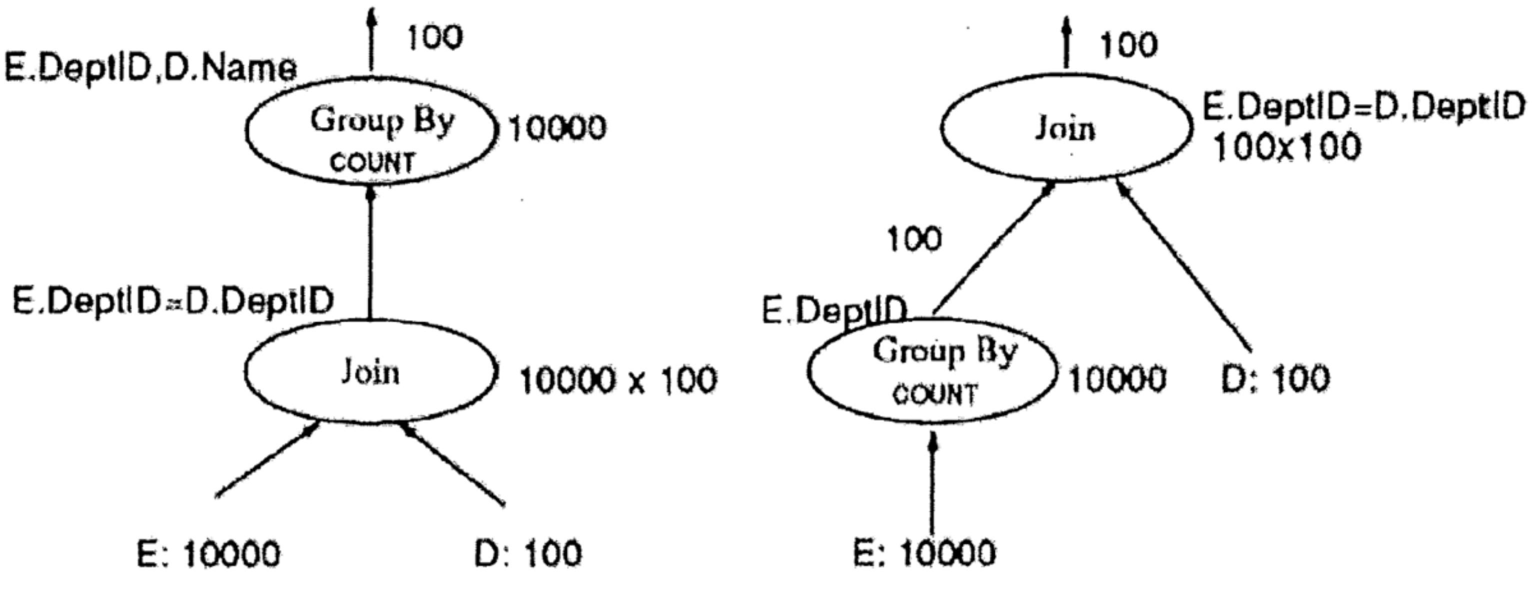

Plan 1: Group by after join

Plan 2: Group by before join

Partial group by can also reduce cost

- Example: first aggregate total sales for all products, later aggregate sales for each division
- More on this topic in the group discussion

Search Space – Multi-Block Query

Merging nested subqueries

```
SELECT Emp.Name
FROM Emp
WHERE Emp.Dept#  IN
      SELECT Dept.Dept#  FROM Dept
      WHERE Dept.Loc='Denver'
      AND Emp.Emp# = Dept.Mgr
```

Nested query (correlated)

```
SELECT E.Name
FROM Emp E, Dept D
WHERE E.Dept# = D.Dept#
AND D.Loc = 'Denver' AND E.Emp# = D.Mgr
```

Unnested query

Search Space – Multi-Block Query

Merging nested subqueries

- Requires outerjoins when aggregation is present
- Nice body of work on doing this in an algebraic framework

```
SELECT Emp.Name
FROM Emp
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Nested query (correlated)

```
SELECT E.Name
FROM Emp E, Dept D
WHERE E.Dept# = D.Dept#
AND D.Loc = 'Denver' AND E.Emp# = D.Mgr
```

Unnested query

Search Space – Multi-Block Query

Merging nested subqueries

- Requires outerjoins when aggregation is present
- Nice body of work on doing this in an algebraic framework

Semijoin-like techniques for multi-block queries

- Send projected list from A to B to reduce the cost of evaluating B
- More on semi-joins in distributed databases in later lectures

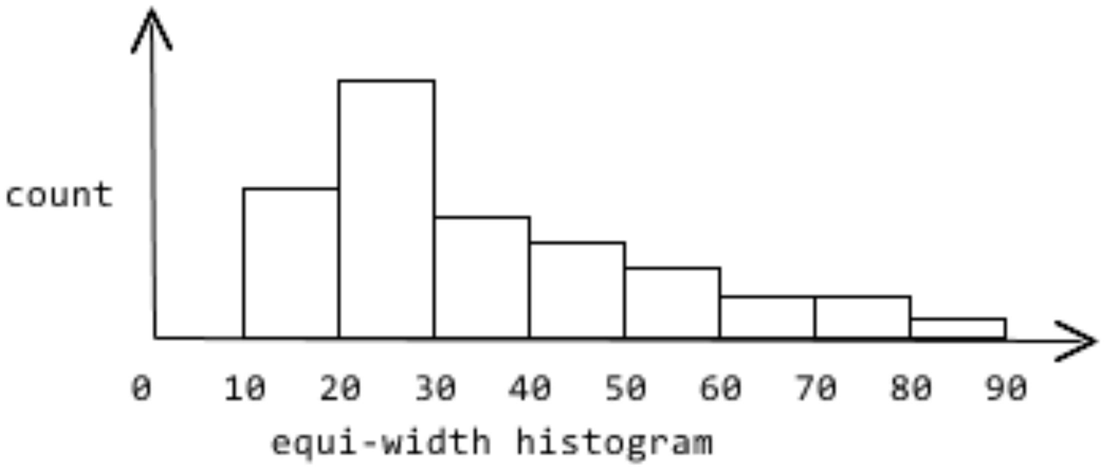
```
CREATE VIEW DepAvgSal As (
        SELECT  E.did,  Avg(E.Sal)  AS  avgsal
        FROM Emp E
        GROUP BY E.did)
SELECT E.eid, E.sal
FROM Emp E, Dept D, DepAvgSal V
WHERE  E.did    =  D.did  AND  E.did  =  V.did
AND E.age < 30 AND D.budget > 100k
AND E.sal > V.avgsal
```

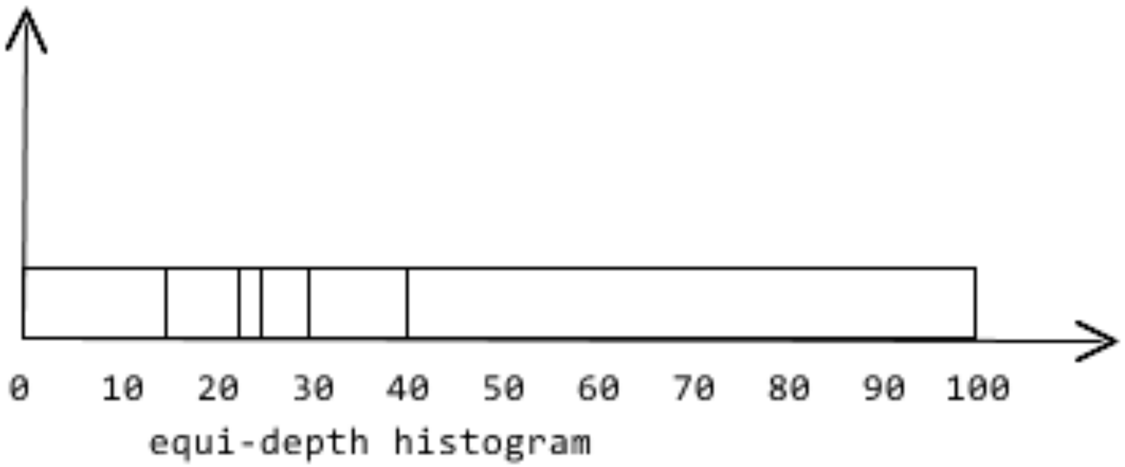
Cost Estimation

System R: Cardinalities

Many commercial systems: **histograms**

- More buckets lead to higher accuracy but more memory/storage consumption
- Good only for single column: 2D histogram





Cost Estimation

System R: Cardinalities

Many commercial systems: **histograms**

- More buckets lead to higher accuracy but more memory/storage consumption
- Good only for single column: 2D histogram

Statistics collected through data sampling => error prone

- Statistic errors propagate quickly. Can be disastrous

Cost computation

- Many system parameters: hardware properties, data distribution, buffer utilization, data storage layout, etc.

Enumeration

Extensible optimizers (Example: Starburst and Volcano)

- Add new join algorithms, new operators, new cost models

Volcano (powering SQL server)

- Universal application of rules
  - Transformation rules: map one algebraic expression to another
  - Implementation rules: map algebraic expression to operator trees
  - Top-down dynamic programming technique

Other Considerations

Distributed databases

- Communication cost

User defined function (UDF)

- Hard to estimate the cost of a UDF

Materialized views

- Reuse materialized views across queries
- General problem undecidable

Miscellaneous

- Mid-flight query re-optimization
- Resources to consider (e.g., memory, power, cost)
- Fuzzy queries in text/multimedia databases

Q/A – Query Optimization-2

Why unnest a query?

Modern query optimization?

- Distributed/parallel, cloud, heterogeneous hardware

Why linear joins more common than bushy joins?

Given a query optimizer, does it matter how a query is written?

What is a star schema?

How does statistical information propagate?

Group Discussion

```
SELECT      JOB.title, count(*)
FROM        JOB, EMP, DEPT
WHERE       JOB.jid = EMP.jid
AND         EMP.did = DEPT.did
AND         DEPT.location="Madison"
GROUP BY    JOB.title
```

|EMP| = 10000 tuples
|DEPT| = 100 tuples
|JOB| = 10 tuples

Consider only nested loop join and only the cost in terms of the **# comparisons** in the join (note that which relation is inner vs. outer in a join does not matter in this case)

Q1: If only one department is in Madison, what's the cheapest plan?
(hint: group-by can be partially pushed down)
Q2 [optional]: If all departments are in Madison, what's the cheapest plan?

Before Next Lecture

Submit discussion summary to https://wisc-cs764-f20.hotcrp.com

- Title: **Lecture 5 discussion. group ##**
- Authors: Names of students who joined the discussion
- Summary submission Deadline: **Tuesday 11:59pm**

Before next lecture, submit review for

- Jim Gray, et al., Granularity of Locks and Degrees of Consistency in a Shared Data Base. Modelling in Data Base Management Systems 1976.