Outline

- Introduction
- Background
- Distributed DBMS Architecture
- Distributed Database Design
- Distributed Query Processing
  - Query Processing Methodology
  - Distributed Query Optimization
- Distributed Transaction Management (Extensive)
- Building Distributed Database Systems (RAID)
- Mobile Database Systems
- Privacy, Trust, and Authentication
- Peer to Peer Systems
Useful References

- Textbook *Principles of Distributed Database Systems*, Chapter 7
Distributed Query Processing Methodology

CONTROL SITE

Calculus Query on Distributed Relations

Query Decomposition

Algebraic Query on Distributed Relations

Data Localization

Fragment Query

Global Optimization

Optimized Fragment Query with Communication Operations

GLOBAL SCHEMA

FRAGMENT SCHEMA

STATS ON FRAGMENTS

LOCAL SCHEMAS

LOCAL SITES

Optimized Local Queries

Optimized Fragment Query with Communication Operations

Global Optimization

Local Optimization

Data Localization

Fragment Query
Restructuring

- Convert relational calculus to relational algebra
- Make use of query trees
- Example

Find the names of employees other than J. Doe who worked on the CAD/CAM project for either 1 or 2 years.

```sql
SELECT ENAME
FROM EMP, ASG, PROJ
WHERE EMP.ENO = ASG.ENO
AND ASG.PNO = PROJ.PNO
AND ENAME ≠ "J. Doe"
AND PNAME = "CAD/CAM"
AND (DUR = 12 OR DUR = 24)
```
Restructuring – Transformation Rules

- Commutativity of binary operations
  - $R \times S \Leftrightarrow S \times R$
  - $R \bowtie S \Leftrightarrow S \bowtie R$
  - $R \cup S \Leftrightarrow S \cup R$

- Associativity of binary operations
  - $(R \times S) \times T \Leftrightarrow R \times (S \times T)$
  - $(R \bowtie S) \bowtie T \Leftrightarrow R \bowtie (S \bowtie T)$

- Idempotence of unary operations
  - $\Pi_{A'}(\Pi_{A'}(R)) \Leftrightarrow \Pi_{A'}(R)$
  - $\sigma_{p_1(A_1)}(\sigma_{p_2(A_2)}(R)) = \sigma_{p_1(A_1) \land p_2(A_2)}(R)$
  - where $R[A]$ and $A' \subseteq A$, $A'' \subseteq A'$ and $A' \subseteq A''$

- Commuting selection with projection
Restructuring – Transformation Rules

- Commuting selection with binary operations
  - $\sigma_{p(A)}(R \times S) \iff (\sigma_{p(A)}(R)) \times S$
  - $\sigma_{p(A_i)}(R \bowtie (A_j, B_k) S) \iff (\sigma_{p(A_i)}(R)) \bowtie (A_j, B_k) S$
  - $\sigma_{p(A_i)}(R \cup T) \iff \sigma_{p(A_i)}(R) \cup \sigma_{p(A_i)}(T)$
  where $A_i$ belongs to $R$ and $T$

- Commuting projection with binary operations
  - $\Pi_C(R \times S) \iff \Pi_{A'}(R) \times \Pi_{B'}(S)$
  - $\Pi_C(R \bowtie (A_j, B_k) S) \iff \Pi_{A'}(R) \bowtie (A_j, B_k) \Pi_{B'}(S)$
  - $\Pi_C(R \cup S) \iff \Pi_C(R) \cup \Pi_C(S)$
  where $R[A]$ and $S[B]$; $C = A' \cup B'$ where $A' \subseteq A$, $B' \subseteq B$
Example

Recall the previous example:
Find the names of employees other than J. Doe who worked on the CAD/CAM project for either one or two years.

SELECT ENAME
FROM PROJ, ASG, EMP
WHERE ASG.ENO=EMP.ENO
AND ASG.PNO=PROJ.PNO
AND ENAME≠“J. Doe”
AND PROJ.PNAME=“CAD/CAM”
AND (DUR=12 OR DUR=24)
Equivalent Query

\[ \pi_{\text{ENAME}} \]

\[ \sigma_{\text{PNAME}=\text{"CAD/CAM"} \land (\text{DUR}=12 \lor \text{DUR}=24) \land \text{ENAME} \neq \text{"J. DOE"}} \]

\[ \bowtie \text{PNO} \land \text{ENO} \]

\[ \text{ASG} \quad \text{PROJ} \quad \text{EMP} \]
Restructuring
Cost Functions

- Total Time (or Total Cost)
  - Reduce each cost (in terms of time) component individually
  - Do as little of each cost component as possible
  - Optimizes the utilization of the resources
    \[\downarrow\]
    Increases system throughput

- Response Time
  - Do as many things as possible in parallel
  - May increase total time because of increased total activity
Total Cost

Summation of all cost factors

Total cost = CPU cost + I/O cost + communication cost

CPU cost = unit instruction cost * no. of instructions

I/O cost = unit disk I/O cost * no. of disk I/Os

communication cost = message initiation + transmission
Total Cost Factors

- **Wide area network**
  - message initiation and transmission costs high
  - local processing cost is low (fast mainframes or minicomputers)
  - ratio of communication to I/O costs = 20:1

- **Local area networks**
  - communication and local processing costs are more or less equal
  - ratio = 1:1.6
Response Time

Elapsed time between the initiation and the completion of a query

Response time = CPU time + I/O time + communication time

CPU time = unit instruction time * no. of sequential instructions

I/O time = unit I/O time * no. of sequential I/Os

communication time = unit msg initiation time * no. of sequential msg + unit transmission time * no. of sequential bytes
Example

Assume that only the communication cost is considered.

Total time = 2 * message initialization time + unit transmission time * (x+y)

Response time = max \{time to send x from 1 to 3, time to send y from 2 to 3\}

time to send x from 1 to 3 = message initialization time + unit transmission time * x

time to send y from 2 to 3 = message initialization time + unit transmission time * y