Query Processing and Optimization

Rose-Hulman Institute of Technology

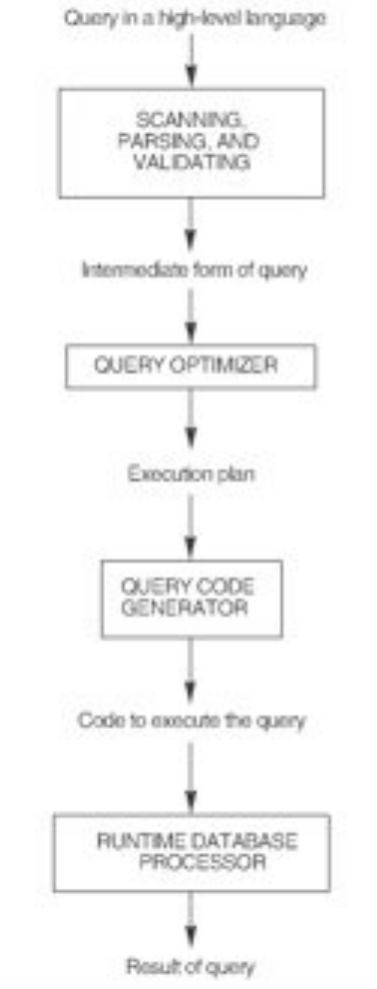
Curt Clifton

Outline

- Basic Optimization Approach
- Algorithms for Processing Queries
- Pipelining
- Techniques for Automatic Query Optimization

Introduction to Query Processing

- What is query optimization?
- Typically intermediate form is a *query tree*



From SQL to Relational Algebra

- **Query block**: the basic unit that can be translated into the algebraic operators and optimized
- Nested queries become separate query blocks
- Aggregate operators in SQL require extended algebra
- Example…

Example Translation

```
SELECT    LNAME, FNAME
FROM      EMPLOYEE
WHERE     SALARY > (    SELECT    MAX (SALARY)
                        FROM      EMPLOYEE
                        WHERE     DNO = 5);
```

```
SELECT    LNAME, FNAME
FROM      EMPLOYEE
WHERE     SALARY > C
```

$\pi_{\text{LNAME, FNAME}} (\sigma_{\text{SALARY}>C}(\text{EMPLOYEE}))$

```
SELECT    MAX (SALARY)
FROM      EMPLOYEE
WHERE     DNO = 5
```

$\mathcal{F}_{\text{MAX SALARY}} (\sigma_{\text{DNO}=5} (\text{EMPLOYEE}))$

What Next?

- Queries reduced to query trees in relational algebra
- DBMS considers various algorithms for processing query
- Rewrites tree to use “best” algorithms
- Variety of algorithms exist to solve various query problems

Problem: Sorting Huge Datasets

- Use **external sorting**
- Phase 1:
  - Load *n* pages into memory, as many as fit (a "run")
  - Sort them and save back to disk
  - Repeat until all runs are sorted
- Phase 2:
  - Perform an (*n*-1)-way merge
    - One page for "top" of each of n-1 runs
    - One page for "bottom" of merge results
  - Repeat until done

Problem: Selecting Subset of Rows

- Linear search:
  - Last resort, unless file is small
- Binary search:
  - For ordered data without an index
- Using an index for equality comparisons:
  - Just look up the record

Problem: Selecting Subset of Rows

- Using a primary index for order comparisons:
  - Find edge of range using index
  - Scan from there
- Using a secondary index for order comparisons:
  - Find edge of range using index
  - Scan leaf nodes of index from there, loading data based on pointers

Select With Complex Condition

- Simple conjunctive selection:
  - Pick one condition for which some previous method would work
  - Use brute force to filter those results based on other conditions
- Conjunctive selection with a composite index:
  - Works if index covers all attributes in the complex condition

Select With Complex Condition

- Conjunctive selection by intersection of record pointers:
  - Suppose:
    - Secondary indexes are several fields in condition
    - Indexes include record pointers
  - Then:
    - Use indexes to get sets of the record pointers for conjuncts
    - Take intersection of pointer sets
    - Then retrieve actual records

Problem: Joining Two Tables

- Nested-loop join (brute force):
  - Last resort unless tables are small
- Single-loop join when one table has index
  - Loop over one table
  - Use index to find matches in other table

Problem: Joining Two Tables

- Sort-merge join when both tables sorted by join attributes
  - Scan both files matching the records that have the same values for join attributes

Problem: Combining Multiple Ops.

- Generating and saving temporary files is time expensive
- So, avoid constructing temporary results
- Pipeline the data through multiple operations:
  - Pass the result of a previous operator to the next
  - Page-by-page instead of operation-by-operation
- Example…

Pipelining Example

- SELECT (FName + ' ' + LName) AS Name
  FROM Employee e JOIN Department d
  ON e.DNo = d.DNumber
  WHERE e.Salary < 50000
  AND d.Location <> 'Houston'
- What are the individual operations for this?
- How many ways could this be pipelined?

Picking Algorithms and Plans

- Heuristics
- Cost estimation

Using Heuristics

- Uses pattern matching to transform parts of query tree to a “best” shape
- Patterns based on transformations that are likely to be more efficient:
  - E.g., Apply selection before applying join
  - Why is that likely (naively) to be more efficient?

Cost-based Optimization

- Estimate the costs of a variety of different versions of the query based on:

Cost-based Optimization

- Estimate the costs of a variety of different versions of the query based on:
  - Available indexes
  - Specificity of conditions
  - Statistics on data
  - Disk speed
  - Memory available
  - Block and record sizes
  - Index blocking factors

Issues in Cost-based Optimization

- Accuracy of statistics
- Cost of calculating costs
- Accuracy of estimates of disk speed, memory available
- Shear number of possible execution strategies

Which is Used?

- Cost-based optimization is “taking over”
- SQL Server uses cost-based optimization
- Does NOT try to minimize total cost!

Which is Used?

- Cost-based optimization is “taking over”
- SQL Server uses cost-based optimization
- Does NOT try to minimize total cost!
- Tries to minimize time to initial results