COS 597A:
Principles of
Database and Information Systems

Query Optimization

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Query Optimization

- Query as expression over relational algebraic operations
- Get evaluation (parse) tree
  – Leaves: base relations
  – Interior nodes: operations

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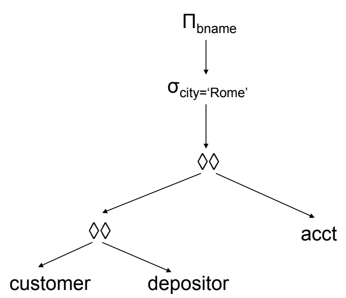
Example

Π_{bname} ($\sigma_{city='Rome'}$ ((customer ◊◊ depositor) ◊◊ acct))



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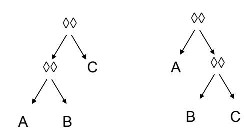
Optimization considerations

- Choice of algorithm at each interior node
  – Cost Estimates
    - We've just studied analysis
- Rearrange tree
  – Use algebra of operations
    - e.g. associativity of JOIN

(A ◊◊ B) ◊◊ C
=
A ◊◊ (B ◊◊ C)



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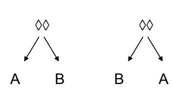
Interaction of algorithm choice and tree arrangement

- Convention: for any nested loop join, left branch represents outer relation
  – Control with commutativity of JOIN
    (A ◊◊ B) = (B ◊◊ A)



- Result of an interior node is input to parent
  - Algorithm affects properties of presentation of result
    -Sorted?
- Cost analysis must proceed bottom up

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Issues

- Need size estimates of result relation
  – # records per page (size of record)
  – # of pages (# of records)
  – Note:
    - page size fixed system parameter
    - Duplicates significantly affect # of records
- Need plan for buffer use
  – Materialize result: write result of interior node to disk
    - Costs of writes for intermediate results count!
  – Intermediate result fits in buffer
    - Algorithm for parent use this?
    - Can save cost of writing result by child & reading result by parent
  – Pipeline result of child as input to parent

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Pipelining

- Parent and child execute concurrently
- Parent and child share buffer space
  - k-page shared (sub)buffer
  - child produces k pages of output – Fill buffer
  - parent consumes k pages of input from child – Empty buffer
  - NO disk write cost child;
  - NO disk read cost parent
- Algorithms of child and parent must support this
  - Child: usually does; produce 1 page output at a time
  - Parent: choice of algorithm critical !

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Algorithms for parent - JOIN

- Block nested loop?
  - Outer relation – ok
    - Read relation once, "chunk" by "chunk"
    - Use shared buffer for "chunk"
  - Inner relation – NO
    - Must re-read *entire* inner relation for every "chunk" of outer
- Index nested loop?
- Sort-merge
- Hash

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Algorithms for parent - JOIN

- Block nested loop?
  - Outer relation – OK
  - Inner relation – NO
- Index nested loop?
  - Outer relation – ok – same as Block nested loop
  - Inner relation – NO
    - Using index
- Sort-merge
- Hash

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Algorithms for parent - JOIN

- Block nested loop?
  - Outer relation – OK
  - Inner relation – NO
- Index nested loop?
  - Outer relation – OK
  - Inner relation – NO
- Sort-merge
  - To sort input relation:
    - Can pipeline from child to group of buffer pages for Stage 1 (Stage 1: sorting individual groups to make runs)
  - If child produced in sorted order, pipeline merge
    - Child must be outer relation if duplicates block nested loop for duplicates
- Hash

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Algorithms for parent - JOIN

- Block nested loop?
  - Outer relation – OK
  - Inner relation – NO
- Index nested loop?
  - Outer relation – OK
  - Inner relation – NO
- Sort-merge – OK
- Hash
  - To partition input relation:
    - Can pipeline from child to buckets in buffer for Stage 1
  - OK

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Allocating buffer pages

- If have simultaneous pipelining up tree
  - How many buffer pages for each child-to-parent exchange?
  - Affects speed of algorithms
- Limit number of simultaneous pipelines
- If no pipeline between child and parent materialize result of child
  - Child writes result to disk
  - Parent reads from disk

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Multi-operation query

- Want plan
  - Parse tree
  - Pipelining plan for each edge
  - Algorithm for each interior node (operation)
- To build plan
  - Consider alternatives
    - ALL?
  - Estimate costs
  - Choose "best"
    - Really "good enough"

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Catalog

- Need info about base relations
- In catalog:
  - For each base relation:
    - # tuples
    - # pages
  - List of existing indexes
  - For each index
    - # distinct search-key values
    - # pages
  - For each tree index
    - Tree height
    - high/low search keys

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Calculating size estimates of result

- Assume
  - independence of attributes of a tuple
  - Uniform distribution of values of each attribute among tuples
- Calculate reduction factor (RF) for # tuples of result
  - Examples:

$\sigma_{f = \text{constant}}$ and index on attribute f:
RF = 1/(# search key values)

$\sigma_{f > \text{constant}}$ and tree index on attribute f:

$$RF = \frac{(\text{high key value}) - \text{constant}}{(\text{high key value}) - (\text{low key value})}$$

  - Estimate # pages output as RF * (# pages input relation)

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Reduction factor of joins

- Estimate # tuples of (R◊◊S) on shared attribute f as

  RF * (# tuples R) * (# tuples S)
  - Looking at join as selection on RXS

- Example: ◊◊ for join attribute f
  - If indexes on R.f and S.f

    RF = 1/max (# key values R.f, # key values S.f)
  - If no indexes, *could* use # distinct values
    - What if real-valued?

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Size of tuples of result

- If attributes of fixed length, calculate
  - Projection: sizes of attributes retained
  - Cross-product RXS: sum of sizes of tuples in R and S
    - Join with single occurrence equal attributes
      - Projection of Cross-product
  - Selection & Union-compatible set operations: no change

- If attributes of variable length, estimate

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Planning

- Know how estimate costs of algorithms
- Know how estimate sizes of results
- How use to make plan for query eval?

interact:
- determine operation order for expression
  - algebraic equivalences
- select algorithm for each operation
  - best depends on operation order

- Can't try all possibilities - exponential time

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Heuristics

Consider k joins: R_1 ◊◊ R_2 ◊◊ … ◊◊ R_k

- Too many parse trees
  - associativity and commutativity
- Example heuristic:

  consider only "Left-deep join trees"
  - IBM system R 1979
  - determines tree shape, not order R_i
  - why this shape?
  - still a lot of trees: k!

Algorithm design

- Observe for (R_1 ◊◊ R_2 ◊◊ … R_{k-1})◊◊ R_k :
  - once decide least-cost way do ( ) actual order compute w/in ( ) not affect best choice for ( ) ◊◊ R_k
  - whether ( ) result sorted or hashed does affect best choice for ( ) ◊◊ R_k

⇒dynamic programming algorithm

- walk up left-deep tree

Using dynamic programming

For node distance d from leftmost leaf,

- estimate lowest cost of evaluating subtree for each size-(d+1) subset of {R_i}
  1. without regard to order of result records
  2. in each "natural" sorted order of result records
- Use results from child node
- Include pipelining strategy
- Remember best plans and pipelining strategy for each subset
  - can reconstruct order going back down tree
- Running time exponential in k
  - still consider each subset of {R_i}
  - don't consider each order of R_i's at next level

Other operations

- Move selects and projects up/down tree
- Try to push selects down tree

  Pushing projects can also be useful
  - why?
  - not always good idea: destroys indexes
- can include in left-join-tree analysis
- Text has detailed discussion equivalences for relational algebra operations

Index-only Algorithms

If have indexes giving pointers to records for all relations in query, consider:

- Use indexes to execute operations
  - must have right search keys
- Retrieve records only at end
- If need only count, never retrieve full records

Summary

- Have seen in detail how to execute joins
- Have considered execution of other relational alg. op.s
- Have looked at how estimate sizes of results
- Have briefly considered one heuristic for making plan for several joins
  - restrict to left-deep trees
- Have looked briefly at planning when relational alg. expr. has more than just joins