Mid-Query Re-Optimization

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Query Optimization

- Ideally an optimal plan should be found. However, this is not the case especially for complex queries.
- Optimizers are unable to accurately estimate the cost of a complex execution plan. Why?
    - Simplified cost model
    - Out-of-date statistics
    - Exponential error
    - Insufficient information about the runtime system
    - OOD or user-defined datatypes do not fit in the cost model.

Query Optimization

- Solutions:
  - Competition model: start with multiple execution plans and leave the best one.
  - Dynamic query plans: statistics during optimization are stored in the plan. Before execution check against the statistics catalog.
  - Query Scrambling: re-optimizes only if data from a source arrives slowly, not relevant

Query Optimization

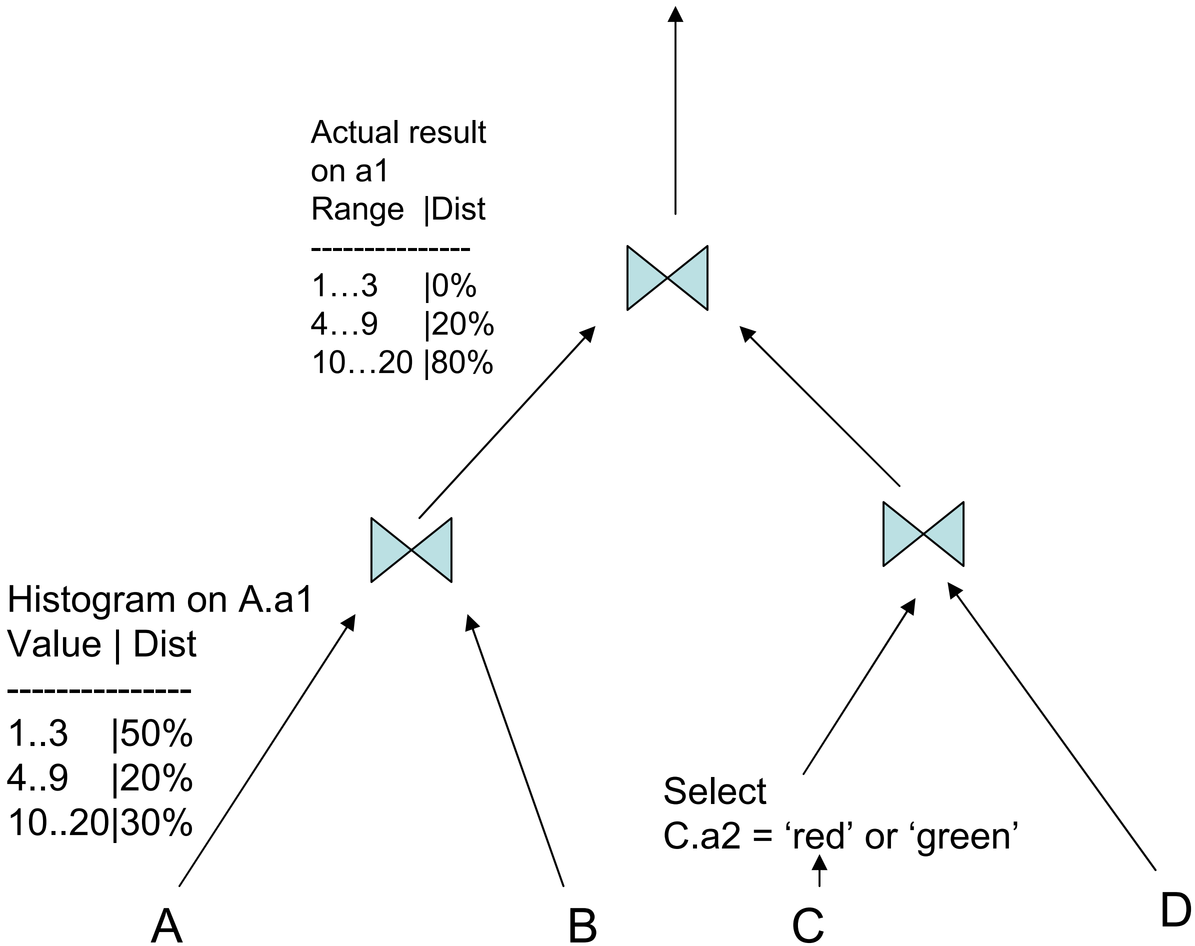
- More solutions:
  - Parametric query optimization algorithms: one plan that is a combination of a number of subplans each of which is optimal for a given set of values. In runtime decide which precompiled plan to choose. Sounds good but hard to create from a great space of possibilities.
  - Mid-query re-optimization: gather runtime statistics and fix the remainder of the query (our discussion).

Complex Queries

- Mid-Query optimization mainly addresses complex queries
- Why are they evil?
  - They are long and complex

    (Q: Find all climbers below average age that are not authors with at least one publication and have rented at least one boat, red or green in the past 2 weeks.)
  - Nested operators cause cost model errors to grow exponentially
  - It is hard to predict their behavior based on initial estimates (which is what optimizers have)
  - Operators share memory
  - Pipeline stalls due to binary operators

The problem: Evil Queries



The Algorithm

- Detects if a query is suboptimal and re-optimizes the remainder of the query.
- Features of the algorithm:
  - Execution plan modification
  - Resource reallocation (memory, scheduling?, others?)
  - Keeping the overhead low
  - Annotated execution plan: maintains statistics at key points in the tree structure
  - Runtime statistics: gather statistics during query execution

Runtime Statistics

- Tools:
  - Statistic collector operators: physical logic operators just like selections, joins etc.
- Decisions:
  - What kind of statistics to collect
  - Where to insert statistics collector operators
- Limitations:
  - Information must be gathered with only one pass over the input
  - Pipelined operators cannot benefit runtime statistics.
  - Execution overhead

Dynamic Resource Reallocation

- Why? Not all operators receive the memory requirements, e.g. operators running in parallel
- How? Reallocate memory based on current statistics. Done by the memory management module

Modifying The Query Plan

- Ok, we want to modify the query plan. We can:
  - discard current execution plan and build a new one. Yeah, sure!
  - stop execution. Re-optimize operators that have not yet started. Sounds easy but hard to implement. If you have a good solution email navin@cs.wisc.edu and dewitt@cs.wisc.edu
  - stop the execution before output reaches next (parent) operator. Save current results (might by I/O costly) and generate a new SQL query. A compromised solution. Easy to implement.

Optimization

- Re-optimization includes:
  - Query plan modification
  - Dynamic resource reallocation
- We optimize when:

$$\left|\frac{T_{improved} - T_{initial}}{T_{initial}}\right| > \theta$$

- Theta is empirically chosen and accounts for overheads

Maintaining Low Overhead

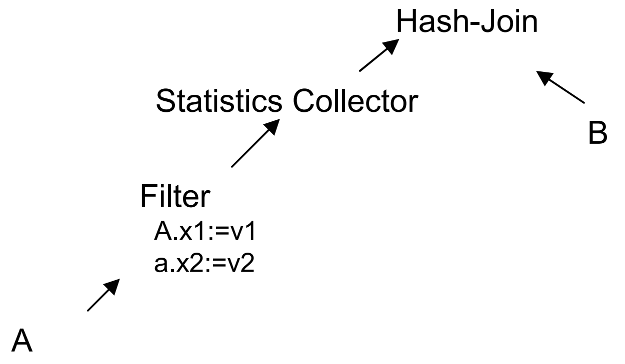
- Getting hyped with gathering statistics and re-optimizing to death might (will) cause a query to run longer.
- Decide on what statistics to use during query execution time
- Process the current plan to insert statistics collector operators with a heuristic algorithm
- Do not insert statistics operators in simple queries or queries expected to run fast.

Algorithm For Inserting Statistics Collectors

- Input: annotated execution plan, maximum accepted overhead fraction
- Output: annotated execution plan extended with statistics operators
- Heuristic approach determines inaccuracy potential (low, medium, high) of the statistics of an annotated plan
  - Determine effectiveness of possible statistic collectors based on inaccuracy potential
  - Sort possible statistics operators on effectiveness and iteratively delete the lowest effective operator until expected computing time drops below maximum accepted overhead

Rules of Thumb

- Statistics collectors are inserted after filtering operators and before the join operators



•The inaccuracy potential for non-equi-joins is always high
•Detailed (serial) histograms have low inaccuracy potential
•The inaccuracy potential of a selection with two inputs is one level higher than its inputs.
•The inaccuracy potential of an equi-join not over a key attribute is one level higher than its inputs

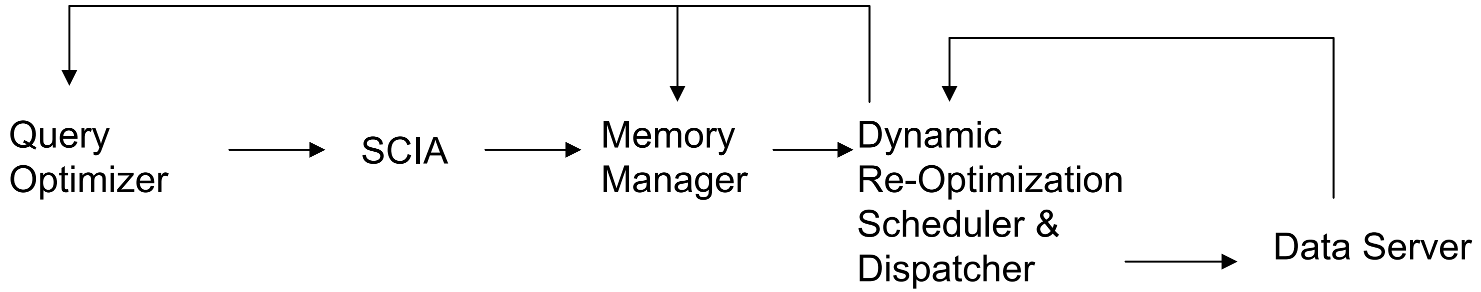
All Comes Together

- Step by step:
  - Conventional optimizer generates a conventional plan
  - Statistics collector algorithm inserts statistics operators ensuring does not overload the plan by some given fraction
  - The final plan (annotated) is then executed
  - Data from statistics operators is used to generate a better cost estimate E.
  - E is compared to the optimizer's estimate C. If E + overhead is much better than C then generate a new plan and repeat from the beginning

Implementation

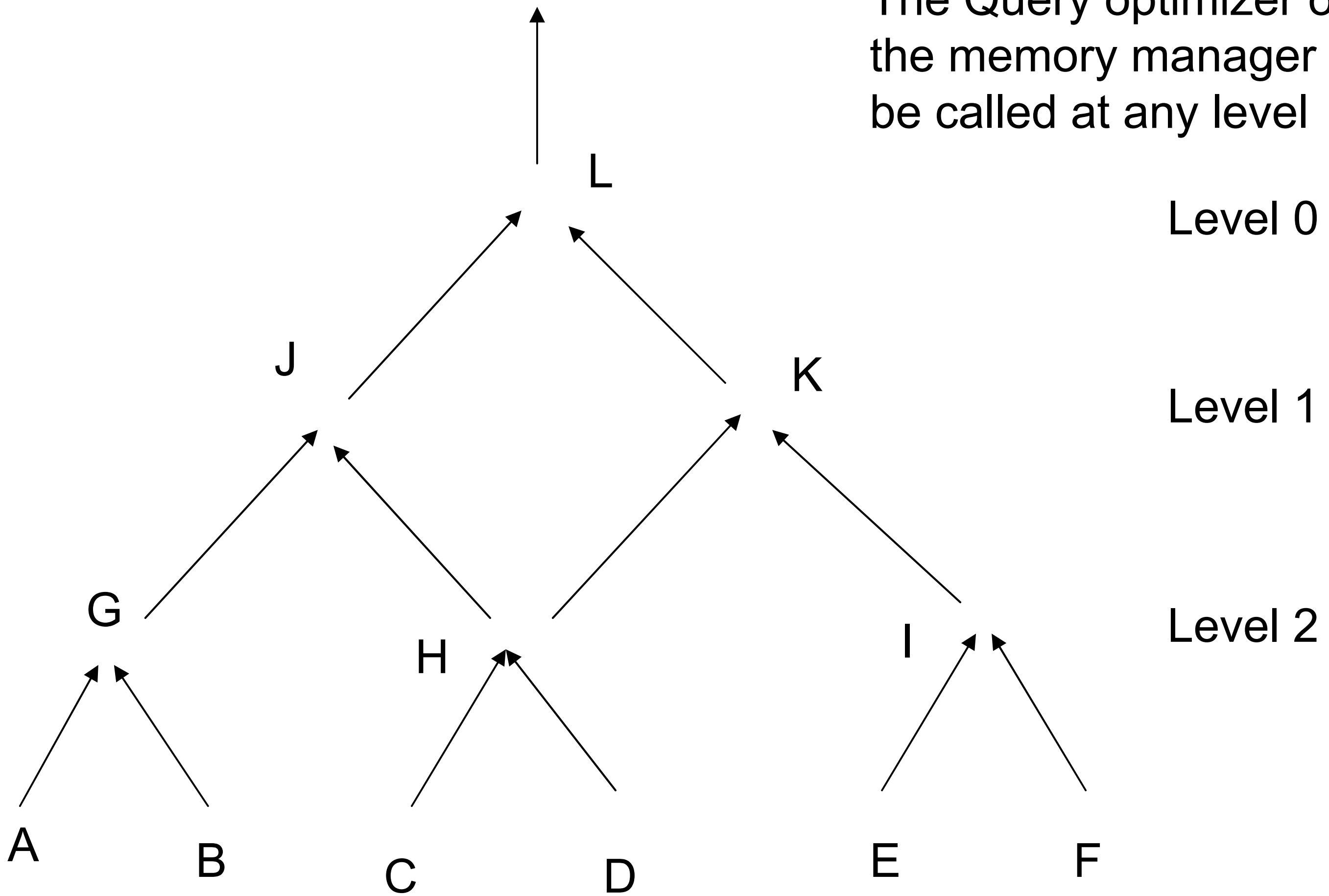
- The algorithm is implemented in the Paradise database system
- Components: query optimizer, memory manager, scheduler & dispatcher, data server.
- Algorithm uses dynamic programming (all cool algorithms do so!)
- Statistics are based on histograms. One page is reserved for histograms updates on per-tuple basis.

More


Query
Optimizer
SCIA
Memory
Manager
Dynamic
Re-Optimization
Scheduler &
Dispatcher
Data Server

Even More

The Query optimizer or the memory manager can be called at any level



Results

- Simple queries do a little worse (5% overhead)
- Medium queries have some to none benefit
- Complex queries benefit a lot
- Results are consider to be excellent and are as expected. The algorithm was never supposed to be a moon walker.

Conclusion

- It works!