Optimizing the Optimizer

Principles of Modern Database Systems
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Randomized query optimization

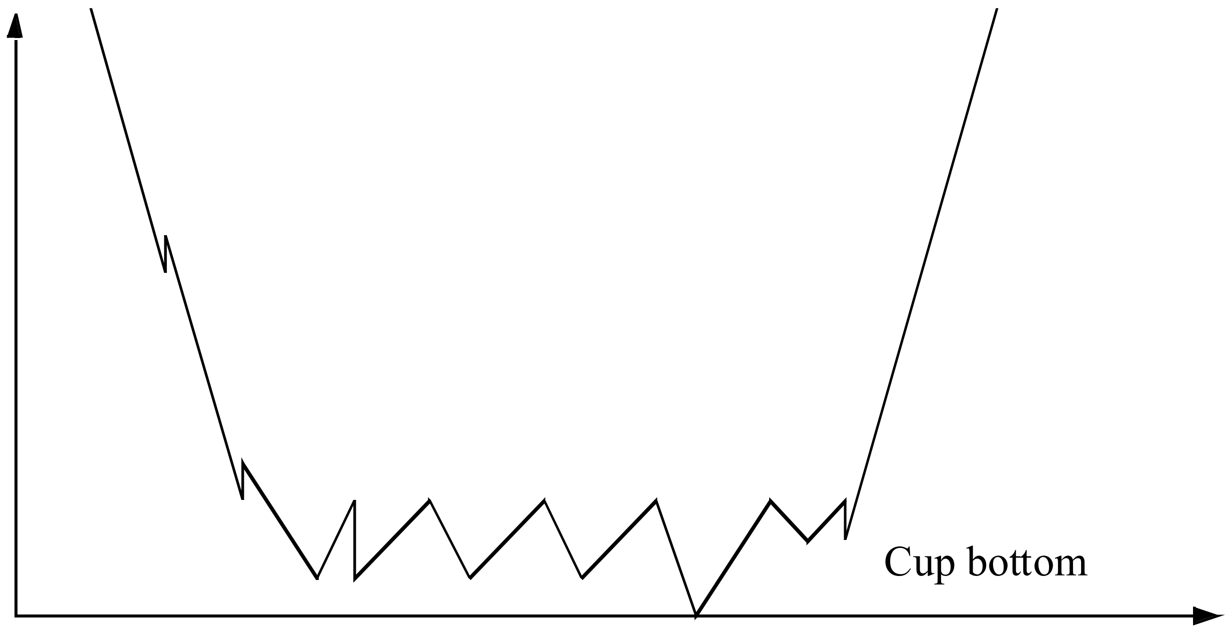
Query optimization is a combinatorial optimization problem

- Each solution is a state in space, i.e. a node in a graph that includes all solutions.
- Each state has associated cost using some cost function.
- Goal: Find state with lowest cost.

Randomized optimization: Use various methods based on random generation of solutions followed by costing

Search space

Works well when many bottoms:



Hillclimbing good to guarantee to find one solution!

Terminology for randomized algorithms:

- Perform *random walks* through state space via a series of moves.
- A move originates in a *source state* and takes us into a *destination state*.
- The states reachable in one move from one state S is called *neighbours* of S.
- A move is *uphill* (*downhill*) if the cost of the source state is lower (higher) than the cost of the destination state.
- A state is *local minimum* if all neighbours are uphill.
- A state is *global minimum* if every other state is downhill.
- A state is a *plateau* if it has no downhill neighbour, but can reach downhill state without uphill moves.

Iterative improvement, II

- Idea:

1. Start at random state.
2. Move to randomly chosen downhill neighbour.
3. Repeat until stopping condition reached.

- Repeat algorithm over and over.
- The more times, the more likely to reach global optimum.

II algorithm:

```
while not(stopping_condition) do
    S = random state
    while not(local_minimum(S) do
        Si' = random state in neighbours(S)
        if(cost(S')<cost(S)) then minS = S'
return(minS)
```

Simulated annealing, SA

- Local optimization in II performs only downhill moves
- SA accept uphill moves too with some probability
- Avoid being caught in high cost local minimum
- Algorithm originally developed for annealing of crystals

SA idea/terminology

- Inner loop of SA called *stage*.
- Each stage performed under fixed value of parameter T, the *temperature*.
- Temperature controls probability of accepting uphill move, Pu
- Pu = $e^{-DC/T}$, where DC difference in cost between old and new state.
- Higher temperature => More likely to accept uphill move
- Higher DC => Less likely to accept uphill move
- The end of a stage reached when algorithm reached equilibrium.
- After each state lower T according to some function.
- New stage begins.
- Stop algorithm when considered frozen, i.e. T=0.

Simulated Annealing, SA, algorithm

```
S = S0
T = T0
minS = S
while not(frozen) do
    while not(equilibrum) do
            S' = random state in neighbours(S)
            DC = cost(S') - cost(S)
            if(DC < 0) then S = S'
            if(DC > 0) then S = S' with probability e^(DC/T)
            if(cost(S) < cost(minS)) then minS = S
    T = reduce(T)
return(minS)
```

Two phase optimization

- Combination of II and simulated anneiling
  A.Swami, *SIGMOD 1989:*
  Optimization of Large Join Queries: Combining Heuristics and Combinatorial Techniques

- Amos II variant (II + *sequence heuristics*):
  http://user.it.uu.se/~udbl/Theses/JoakimNasMSc.pdf

```
optmethod('randomopt');
optlevel(50,1000);
```

Summary cost-based optimization

- With a good cost model it provides the optimal database execution plan
- Without it much less scalable query execution might occur
- Cost of optimization high
- There are alternative faster methods (e.g. randomized or heuristic optimization) but they give suboptimal plans
- Cost model need not be perfect as it is used only for comparing plans
- However, error in cost models may cause problems when:
  - Queries are large (errors multiplied)
  - There are statistical dependencies (independence assumed)
  - Costs are varying (e.g. network speed)
  - All data not known (e.g. parameterized queries, *prepare* in JDBC

Prepared queries and the query cache

- Dynamic query compilation in program
- In JDBC (ODBC and other APIs)
- Idea:

  ```
  p = prepare("select name from person where name = ?")
  ….
  Execute(p, "Tore")
  ```

  Programmers make prepare statement in beginning of program.
  The compiled query is forgotten at end of session.
- Problems with *prepare*:
  - Programmer unaware of it!
  - Slow startup time for programs
- Modern DBMSs always have a *query cache*:
  - S*erver* executes the preparations and saves in hashtable keyed by prepare string (including ?)
  - Saves start-up time
  - *prepare* followed by *execute* in loop efficient!

Dynamic query optimization

- Useful when
  - Queries are dynamic (i.e. dynamic strings sent to DBMS)
  - Parameterized queries (i.e. *prepare* in JDBC)
  - Cost changes during run
- Optimization of parameterized queries:
  prepare(“select name from person where income > ?”)
  Index on *income*
- Different plans depending on parameter value provided at executio
  time:
  Large value: Use index scan
  Small value: Use table scan

Dynamic query optimization

- One solution:
  R.L.Cole & G:Graefe: *Optimization of Dynamic Query Evaluation Plans*, SIGMOD Conf. 1994
- Idea:
  Make several plans dependent on parameter
  Keep value intervals when plan applies
  Let prepare choose plan depending on actual parameter value
- Problem:
  Even slower query optimization
  Not useful when costs change dynamically (e.g.web)

Symmetric hash join

- Problems to solve:
  - Hash join favors one incoming argument
  - Not good in web environment
- For example:
  select s.sales+d.sales from SWStores s, DKsstores d
  where s.prod=d.prod
- Assume s and d accessed through slow network connections
- Hash join on s will stall if s blocks and vice versa

Symmetric hash join

- Solution:
  W. Hong and M. Stonebraker. Optimization of Parallel Query Execution Plans in XPRS. *Distributed and Parallel Databases*, 1(1):9–32, 1993.
  A. N. Wilschut and P. M. G. Apers. *Dataflow Query Execution in a Parallel Main-Memory Environment*. PDIS 1991
- Idea:
  Make hash table on both operands
  Fill hash tables through two threads
  Emit tuples when match occurrs
- Space overflow: spill tables to disk

Adaptive query optimization

- Problems to solve:
  - Startup time for queries
  - Dynamically changing costs
- Main paper:
  R. Avnur and J. M. Hellerstein. *Eddies: Continuously adaptivequery processing*, SIGMOD, 2000.
- Idea:
  - Implement a pipelined multi-select-project-join operator, the *eddi* operator
  - One *eddie* operator adapts execution so to always work on data from incoming stream that delivers values
  - Work where data available in in-buffer
  - Buffer up intermediate results

Eddies (con.)

- Advantage:
  - Totally adaptive
  - Very low start-up cost
- Problems:
  - Eddie operator has overhead (25%)
  - Cost-based optimization generates better plans when cost model good
  - Adaptation may slow, bias towards first choice
- Improvement (STAIRS)
  A.Desphande & J.Hellerstein: *Lifting the Burden of History from Adaptive Query Processing*, VLDB 2004
- Idea:
  - Break down *eddie* into smaller operators
  - Allow dynamic rollback-reconfigure-restart