Introduction to Query Optimization

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Optimization

- *So far, we talked about physical implementations. Next step: how do we use them?*

- At the heart of the database engine
- Step 1: convert the SQL query to a logical plan
- Step 2: find a better logical plan, find an associated physical plan
- (Feed the physical plan into the query processor.)

Converting from SQL to Logical Plans

Need to start someplace..

The easy cases:

Select a1, …, an
From R1, …, Rk
Where C

$\pi_{a1,\ldots,an}(\sigma_C(R1 \times R2 \times \ldots \times Rk))$

Select a1, …, an, aggs
From R1, …, Rk
Where C
Group by b1, …, bl

Uses “extended” relational algebra, with gamma and delta

$\pi_{a1,\ldots,an}(\gamma_{b1,\ldots,bm,\ aggs}(\sigma_C(R1 \times R2 \times \ldots \times Rk)))$

In most of these cases, the x will be a $\bowtie$

Optimization: Logical Query Plan

- Now we have one logical plan. Let's try to make it better.
- Ingredient 1: **Algebraic laws**: what are the ways in which an expression or tree may be rewritten without changing the meaning
- Ingredient 2: **Optimizations**: if there are multiple ways to write the same query, which one to choose.
  - Rule-based (heuristics): apply laws that *<u>seem</u>* to result in cheaper plans
  - Cost-based: estimate size and cost of intermediate results, search systematically for best plan

The three components of an optimizer

- Algebraic laws
- A cost estimator
- Optimization
  - Rule based
  - Cost based

Query Optimization: RA Equivalence Rules

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Algebraic Laws

Hold independent of set or bag..

- Commutative and Associative Laws
  - $R \cup S = S \cup R$, $R \cup (S \cup T) = (R \cup S) \cup T$
  - $R \cap S = S \cap R$, $R \cap (S \cap T) = (R \cap S) \cap T$
  - $R \bowtie S = S \bowtie R$, $R \bowtie (S \bowtie T) = (R \bowtie S) \bowtie T$
- Distributive Laws
  - $R \bowtie (S \cup T) = (R \bowtie S) \cup (R \bowtie T)$

Algebraic Laws

- Laws involving selection (set semantics):
  - $\sigma_{C \text{ AND } C'}(R) = \sigma_C(\sigma_{C'}(R)) = \sigma_C(R) \cap \sigma_{C'}(R)$
  - $\sigma_{C \text{ OR } C'}(R) = \sigma_C(R) \cup \sigma_{C'}(R)$
  - $\sigma_C(R \bowtie S) = \sigma_C(R) \bowtie S$
    - When is this true?
      - Certainly true when C involves only attributes of R
      - What if it involves attributes of R and S?
        - For example: R(X, Y), S(Y, Z)
        - Say: Y = 3; X = 3 ^ Z = 5

Laws involving selection (set semantics) Cont.

- $\sigma_C(R - S) = \sigma_C(R) - S$
  - When is this true?
- $\sigma C(R \cup S) = \sigma C(R) \cup \sigma C(S)$
- $\sigma C(R \cap S) = \sigma C(R) \cap S$

Algebraic Laws

- Example: R(A, B, C, D), S(E, F, G)
  - $\sigma_{F=3}(R \bowtie_{D=E} S) =$?
  - $\sigma_{A=5 \text{ AND } G=9}(R \bowtie_{D=E} S) =$?

  - Simplify as much as possible by pushing down predicates
    - As close to the relations as possible

Algebraic Laws

- Example: R(A, B, C, D), S(E, F, G)
  - $\sigma_{F=3}(R \bowtie_{D=E} S) = R \bowtie_{D=E} (\sigma_{F=3}(S))$
  - $\sigma_{A=5 \text{ AND } G=9}(R \bowtie_{D=E} S) = (\sigma_{A=5}(R)) \bowtie_{D=E} (\sigma_{G=9}(S))$

Algebraic Laws

- Laws involving selection (set semantics):
  - $\sigma_{C \text{ AND } C'}(R) = \sigma_C(\sigma_{C'}(R)) = \sigma_C(R) \cap \sigma_{C'}(R)$
  - $\sigma_{C \text{ OR } C'}(R) = \sigma_C(R) \cup \sigma_{C'}(R)$ 🡐 *what about this one?*
  - $\sigma_C(R \bowtie S) = \sigma_C(R) \bowtie S$
    - Only when C involves only attributes of R
  - $\sigma_C(R - S) = \sigma_C(R) - S$
  - $\sigma_C(R \cup S) = \sigma_C(R) \cup \sigma_C(S)$
  - $\sigma_C(R \cap S) = \sigma_C(R) \cap S$

Exercise: Think about which of these hold for bag semantics….

Algebraic Laws

- Laws involving selection (bag semantics??):
  - $\sigma_{C \text{ OR } C'}(R) = \sigma_C(R) \cup \sigma_{C'}(R)$ 🡐 *what about this one?*

Algebraic Laws

- Laws involving projections
  - $\Pi_M(\Pi_N(R)) = \Pi_{M \cap N}(R)$
  - $\Pi_M(R \bowtie S) = \Pi_N(\Pi_P(R) \bowtie \Pi_Q(S))$
    - Where N, P, Q are appropriate subsets of attributes of M that are "needed afterwards"

- Example R(A,B,C,D), S(E, F, G)
  - $\Pi_{A,B,G}(R \bowtie_{D=E} S) = \Pi_{?}(\Pi_{?}(R) \bowtie \Pi_{?}(S))$

Query Optimization: Rule-Based Optimization

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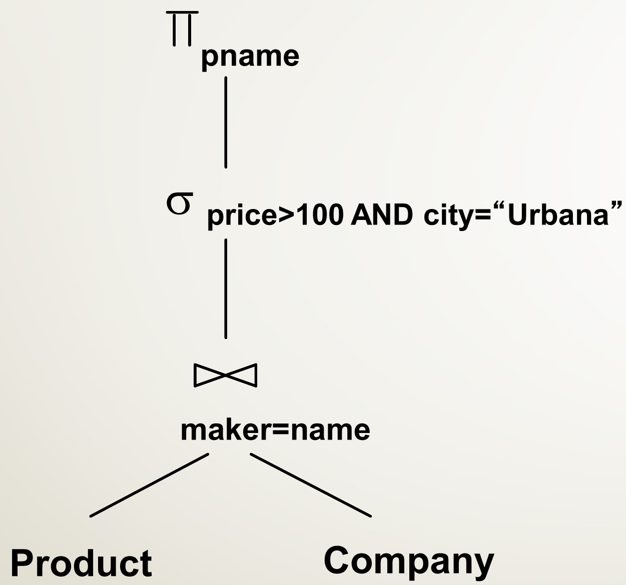
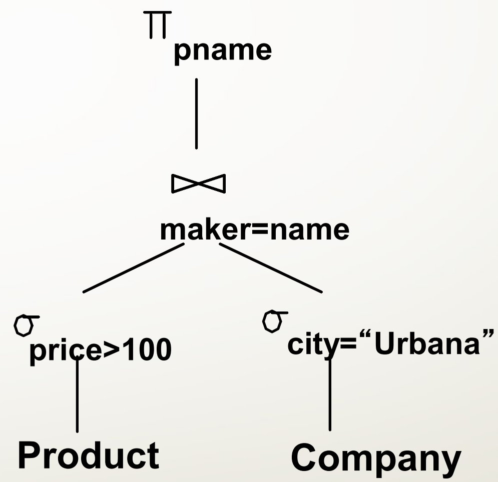
Heuristic Based Optimizations

- Rewriting of logical plan based on specific algebraic laws
- Results in better execution plans most of the time

Heuristic 1: Push selections down

Uses $\sigma_C(R \bowtie S) = \sigma_C(R) \bowtie \sigma_C(S)$





The earlier we process selections, less tuples we need to manipulate higher up in the tree

Pushing selection down: More complex Settings

```
Select   y.name, Max(x.price)
From     product x, company y
Where    x.maker = y.name
GroupBy  y.name
Having   Max(x.price) > 100
```

⇒

```
Select   y.name, Max(x.price)
From     product x, company y
Where    x.maker=y.name and
           x.price > 100
GroupBy  y.name
```

- *For each company, find the maximum price among its products.*
- *But only display (company, maxprice) pair if maxprice > 100*
- Advantage: the size of the join will be smaller.
- Requires transformation rules specific to the grouping/aggregation operators.
- Won't work if we replace Max by Avg.

Heuristic 2

- (In some cases) push selections up, then down
- But ultimately pushed down
- $\sigma_C(R) \bowtie S = \sigma_C(R \bowtie S) = \sigma_C(R) \bowtie \sigma_C(S)$

Typically: apply selections as close to the relations as possible so as to reduce size of intermediate results

Pushing selection up?

Bargain view: for categories with some price<5, find the company that makes the cheapest product in that category, and that price

```
Select   V2.name, V2.price
From     V1, V2
Where    V1.category = V2.category  and
           V1.minprice = V2.price
```

```
Create View V1 AS
Select   x.category,
      Min(x.price) AS minprice
From     product x
Where    x.price < 5
GroupBy  x.category
```

```
Create View V2 AS
Select   y.name, x.category, x.price
From     product x, company y
Where    x.maker=y.name
```

Pushing selection up …

Bargain view: for categories with some price<5, find the company that makes the cheapest product in that category, and that price

```
Select   V2.name, V2.price
From     V1, V2
Where    V1.category = V2.category  and
           V1.minprice = V2.price AND V1.minprice < 5
```

```
Create View V1 AS
Select   x.category,
           Min(x.price) AS minprice
From     product x
Where    x.price < 5
GroupBy  x.category
```

```
Create View V2 AS
Select   y.name, x.category, x.price
From     product x, company y
Where    x.maker=y.name
```

… and then down

Bargain view: for categories with some price<5, find the company that makes the cheapest product in that category, and that price

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Select   y.name, x.category, x.price
From     product x, company y
Where    x.maker=y.name AND x.price < 5
```