

CSE544

Database Statistics

Tuesday, February 15th, 2011

Outline

- Chapter 15 in the textbook

Query Optimization

Three major components:

1. Search space
2. Algorithm for enumerating query plans
3. Cardinality and cost estimation

3. Cardinality and Cost Estimation

- Collect statistical summaries of stored data
- Estimate size (=cardinality) in a bottom-up fashion
 - This is the most difficult part, and still inadequate in today's query optimizers
- Estimate cost by using the estimated size
 - Hand-written formulas, similar to those we used for computing the cost of each physical operator

Statistics on Base Data

- **Collected information for each relation**
 - Number of tuples (cardinality)
 - Indexes, number of keys in the index
 - Number of physical pages, clustering info
 - Statistical information on attributes
 - Min value, max value, number distinct values
 - Histograms
 - Correlations between columns (hard)
- **Collection approach: periodic, using sampling**

Size Estimation Problem

```
S = SELECT list  
FROM R1, ..., Rn  
WHERE cond1 AND cond2 AND . . . AND condk
```

Given $T(R_1), T(R_2), \dots, T(R_n)$
Estimate $T(S)$

How can we do this ? Note: doesn't have to be exact.

Size Estimation Problem

```
S = SELECT list  
FROM R1, ..., Rn  
WHERE cond1 AND cond2 AND ... AND condk
```

Remark: $T(S) \leq T(R1) \times T(R2) \times \dots \times T(Rn)$

Selectivity Factor

- Each condition *cond* reduces the size by some factor called *selectivity factor*
- Assuming independence, multiply the selectivity factors

Example

R(A,B)
S(B,C)
T(C,D)

```
SELECT *  
FROM R, S, T  
WHERE R.B=S.B and S.C=T.C and R.A<40
```

$T(R) = 30k$, $T(S) = 200k$, $T(T) = 10k$

Selectivity of $R.B = S.B$ is $1/3$

Selectivity of $S.C = T.C$ is $1/10$

Selectivity of $R.A < 40$ is $1/2$

What is the estimated size of the query output ?

Rule of Thumb

- If selectivities are unknown, then:
selectivity factor = 1/10
[System R, 1979]

Using Data Statistics

- Condition is $A = c$ /* value selection on R */
 - Selectivity = $1/V(R,A)$
- Condition is $A < c$ /* range selection on R */
 - Selectivity = $(c - \text{Low}(R, A))/(\text{High}(R,A) - \text{Low}(R,A))T(R)$
- Condition is $A = B$ /* $R \bowtie_{A=B} S$ */
 - Selectivity = $1 / \max(V(R,A), V(S,A))$
 - (will explain next)

Assumptions

- Containment of values: if $V(R,A) \subseteq V(S,B)$, then the set of A values of R is included in the set of B values of S
 - Note: this indeed holds when A is a foreign key in R , and B is a key in S
- Preservation of values: for any other attribute C ,
 $V(R \bowtie_{A=B} S, C) = V(R, C) \cup V(S, C)$

Selectivity of $R \bowtie_{A=B} S$

Assume $V(R,A) \leq V(S,B)$

- Each tuple t in R joins with $T(S)/V(S,B)$ tuple(s) in S
- Hence $T(R \bowtie_{A=B} S) = T(R) T(S) / V(S,B)$

In general: $T(R \bowtie_{A=B} S) = T(R) T(S) / \max(V(R,A), V(S,B))$

Size Estimation for Join

Example:

- $T(R) = 10000$, $T(S) = 20000$
- $V(R,A) = 100$, $V(S,B) = 200$
- How large is $R \bowtie_{A=B} S$?

Histograms

- Statistics on data maintained by the RDBMS
- Makes size estimation much more accurate (hence, cost estimations are more accurate)

Histograms

Employee(ssn, name, age)

$T(\text{Employee}) = 25000$, $V(\text{Employee}, \text{age}) = 50$
 $\min(\text{age}) = 19$, $\max(\text{age}) = 68$

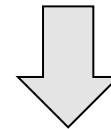
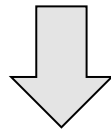
$\sigma_{\text{age}=48}(\text{Employee}) = ?$ $\sigma_{\text{age}>28 \text{ and } \text{age}<35}(\text{Employee}) = ?$

Histograms

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Estimate = $25000 / 50 = 500$ Estimate = $25000 * 6 / 60 = 2500$

Histograms

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Age:	0..20	20..29	30-39	40-49	50-59	> 60
Tuples	200	800	5000	12000	6500	500

Histograms

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Age:	0..20	20..29	30-39	40-49	50-59	> 60
Tuples	200	800	5000	12000	6500	500

Estimate = 1200

Estimate = $2 \cdot 80 + 5 \cdot 500 = 2660$

Types of Histograms

- How should we determine the bucket boundaries in a histogram ?

Types of Histograms

- How should we determine the bucket boundaries in a histogram ?
- Eq-Width
- Eq-Depth
- Compressed
- V-Optimal histograms

Employee(ssn, name, age)

Histograms

Eq-width:

Age:	0..20	20..29	30-39	40-49	50-59	> 60
Tuples	200	800	5000	12000	6500	500

Eq-depth:

Age:	0..20	20..29	30-39	40-49	50-59	> 60
Tuples	1800	2000	2100	2200	1900	1800

Compressed: store separately highly frequent values: (48,1900)

Some Definitions

- [Ioannidis: *The history of histograms*, 2003]
- Relation R, attribute X
- Value set of R.X is $V = \{v_1 < v_2 < \dots < v_n\}$
- Spread of v_k is $s_k = v_{k+1} - v_k$
- Frequency $f_k = \#$ of tuples with $R.X = v_k$
- Area $a_k = s_k \times f_k$

V-Optimal Histograms

- Defines bucket boundaries in an optimal way, to minimize the error over all point queries
- Computed rather expensively, using dynamic programming
- Modern databases systems use V-optimal histograms or some variations

V-Optimal Histograms

Formally:

- The data distribution of $R.X$ is:
 - $T = \{(v_1, f_1), \dots, (v_n, f_n)\}$
- A histogram for $R.X$ with β buckets is:
 - $H = \{(u_1, e_1), \dots, (u_\beta, e_\beta)\}$
- The estimation at point x is: $e(x) = e_i$,
where $u_i \leq x < u_{i+1}$

V-Optimal Histograms

Formally:

- The v-optimal histogram with β buckets is the histogram $H = \{(u_1, g_1), \dots, (u_\beta, f_\beta)\}$ that minimizes:

$$\sum_{i=1, n} |e(v_i) - f_i|^2$$

- Can be computed using dynamic programming

Difficult Questions on Histograms

- Small number of buckets
 - Hundreds, or thousands, but not more
 - WHY ?
- *Not* updated during database update, but recomputed periodically
 - WHY ?
- Multidimensional histograms rarely used
 - WHY ?

Summary of Query Optimization

- Three parts:
 - search space, algorithms, size/cost estimation
- Ideal goal: find optimal plan. But
 - Impossible to estimate accurately
 - Impossible to search the entire space
- Goal of today's optimizers:
 - Avoid very bad plans