

Advanced Database Technology

March 20, 2003

QUERY COMPILATION II

Lecture based on [GUW, 16.4–16.7]

Slides based on
Notes 06–07: Query execution Part I–II
for Stanford CS 245, fall 2002
by Hector Garcia–Molina

This lecture (10–12 AM)

- We assume that we have an **algebraic expression** (tree), and consider:
 - Simple estimates of the **size** of relations given by subexpressions.
 - **Statistics** that improve estimates.
 - Choosing an **order** for operations, using various optimization techniques.
 - Completing the **physical query plan**.

Estimating sizes of relations

The **sizes** of intermediate results are important for the choices made when planning query execution.

- Time for operations grow (at least) linearly with size of (largest) argument.
- The total size can even be used as a crude estimate on the running time.

Statistics for computing estimates

The book suggests several statistics on relations that may be used to (heuristically) estimate the size of intermediate results.

- $T(R)$: # tuples in R
- $S(R)$: # bytes in each R tuple
- $B(R)$: # blocks to hold all R tuples
- $V(R, A)$: # distinct values in R for attribute A

Size estimates for $W = R1 \times R2$

$$T(W) = T(R1) \times T(R2)$$

$$S(W) = S(R1) + S(R2)$$

Question: How good are these estimates?

Size estimate for $W = \sigma_{A=a}(R)$

$$S(W) = S(R)$$

$$T(W) = ?$$

Some possible assumptions

- Values in select expression $A = a$ (or at least one of them) are **uniformly distributed** over the possible $V(R,A)$ values.
- As above, but with uniform distribution over domain with **DOM(R,A)** values.
- **Zipfian** distribution of values.

Selection cardinality

$SC(R,A)$ = expected # records that satisfy equality condition on R.A

$$SC(R,A) = \begin{cases} \frac{T(R)}{V(R,A)} & \text{under first assumption} \\ \frac{T(R)}{DOM(R,A)} & \text{under 2}^{nd} \text{ assumption} \end{cases}$$

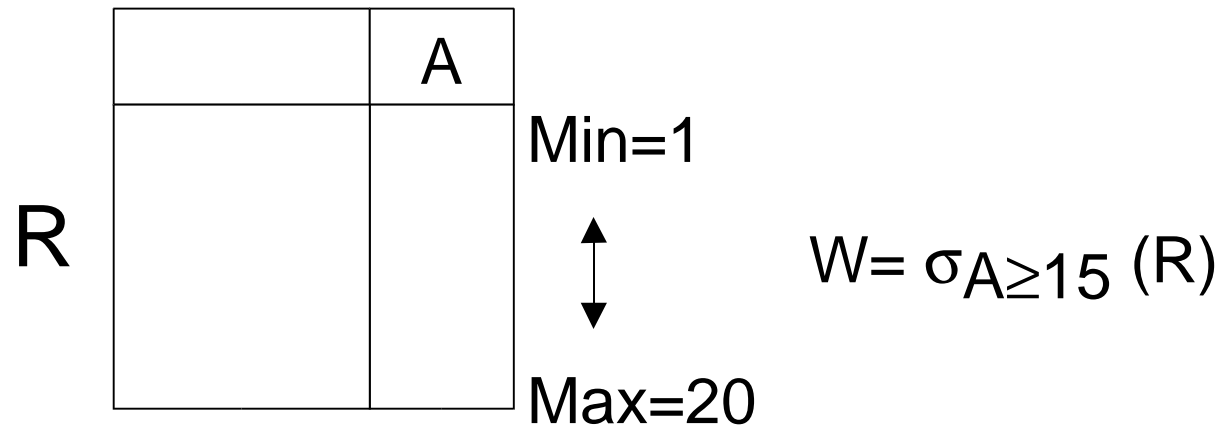
Size estimate for $W = \sigma_{A \geq a}(R)$

$T(W) = ?$

- Suggestion # 1: $T(W) = T(R)/2$.
- Suggestion # 2: $T(W) = T(R)/3$.
- Suggestion # 3 (not in book):
Be consistent with equality estimate.

Example:

Consistency with 2nd equality estimate.



$$f = \frac{20-14}{20} \quad (\text{fraction of range})$$

$$T(W) = f \times T(R)$$

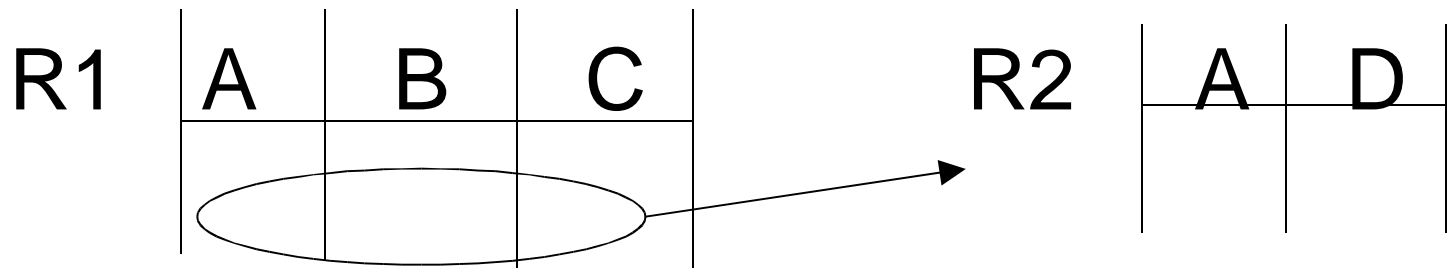
Problem session

Consider the natural join operation on two relations R_1 and R_2 with join attribute A .

- If values for A are uniformly distributed on $\text{DOM}(R_1, A) = \text{DOM}(R_2, A)$ values, what is the expected size of $R_1 \bowtie R_2$?
- What can you say if values for A are instead uniform on respectively $V(R_1, A)$ and $V(R_2, A)$ values?
- What if A is primary key for R_1 and/or R_2 ?

Crude estimate

Values uniformly distributed over domain



This tuple matches $T(R2)/DOM(R2,A)$ so

$$T(W) = \frac{T(R2) T(R1)}{DOM(R2, A)} = \frac{T(R2) T(R1)}{DOM(R1, A)}$$

Assume the same

General crude estimate

Let $W = R_1 \square \rightarrow R_2 \square \rightarrow R_3 \square \rightarrow \dots \square \rightarrow R_k$

$$T(W) = \frac{T(R_1) T(R_2) \dots T(R_k)}{\text{DOM}(R_1, A)^{k-1}}$$

Symmetric wrt. the relations. A rare property...

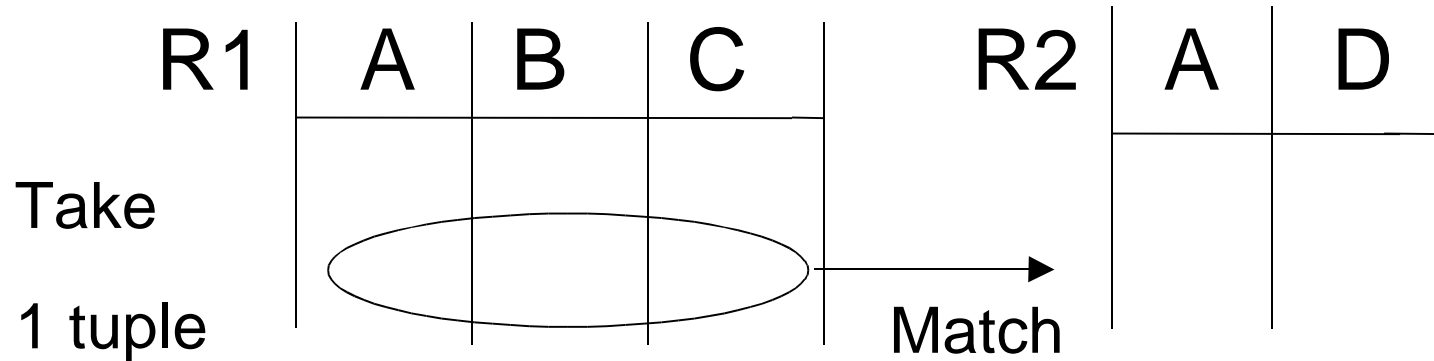
"Better" size estimate for $W = R1 \sqcap \rightarrow R2$

Assumption: Containment of value sets

$V(R1,A) \leq V(R2,A) \Rightarrow$ Every A value in R1 is in R2

$V(R2,A) \leq V(R1,A) \Rightarrow$ Every A value in R2 is in R1

Computing $T(W)$ when $V(R1,A) \leq V(R2,A)$



1 tuple matches with $\frac{T(R2)}{V(R2,A)}$ tuples...

so $T(W) = \frac{T(R2) \times T(R1)}{V(R2, A)}$

General estimate

Let $W = R_1 \rightarrow R_2 \rightarrow R_3 \rightarrow \dots \rightarrow R_k$

$$T(W) = \frac{T(R_1) \dots T(R_k) \min\{V(R_1, A), \dots, V(R_k, A)\}}{V(R_1, A) V(R_2, A) \dots V(R_k, A)}$$

Underlying assumption:

Preservation of value sets

Multiple join attributes

The previous estimates are easily extended to several join attributes A_1, \dots, A_j :

- **New assumption:** Values are **independent**.
- Under assumption 1, the joint values in attributes are uniformly distributed on $V(R, A_1) V(R, A_2) \dots V(R, A_j)$ values.
- Under assumption 2, they are uniform on $DOM(R, A_1) DOM(R, A_2) \dots DOM(R, A_j)$ values.

Other estimates use similar ideas

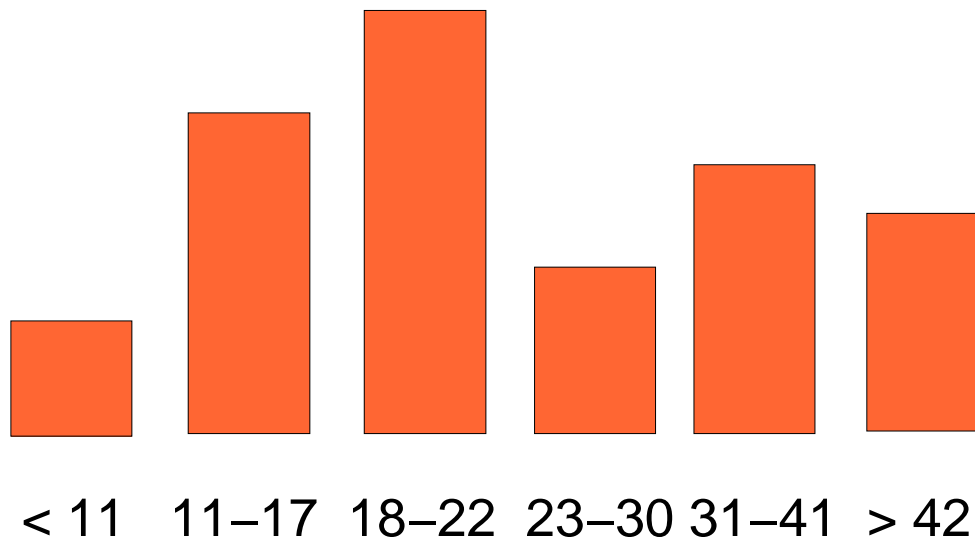
$\Pi_{AB}(R)$ Sec. 16.4.2

$\sigma_{A=a \wedge B=b}(R)$ Sec. 16.4.3

Union, intersection, duplicate elimination,
difference, Sec. 16.4.7

Improved estimates through histograms

- **Idea:** Maintain more info than just $V(R,A)$.
- **Histogram:** Number of values in each of a number of intervals.



Problem session

Consider how histograms could be used when estimating the size of:

- A selection.
- A natural join.

You may assume that both relations have histograms using the same intervals.

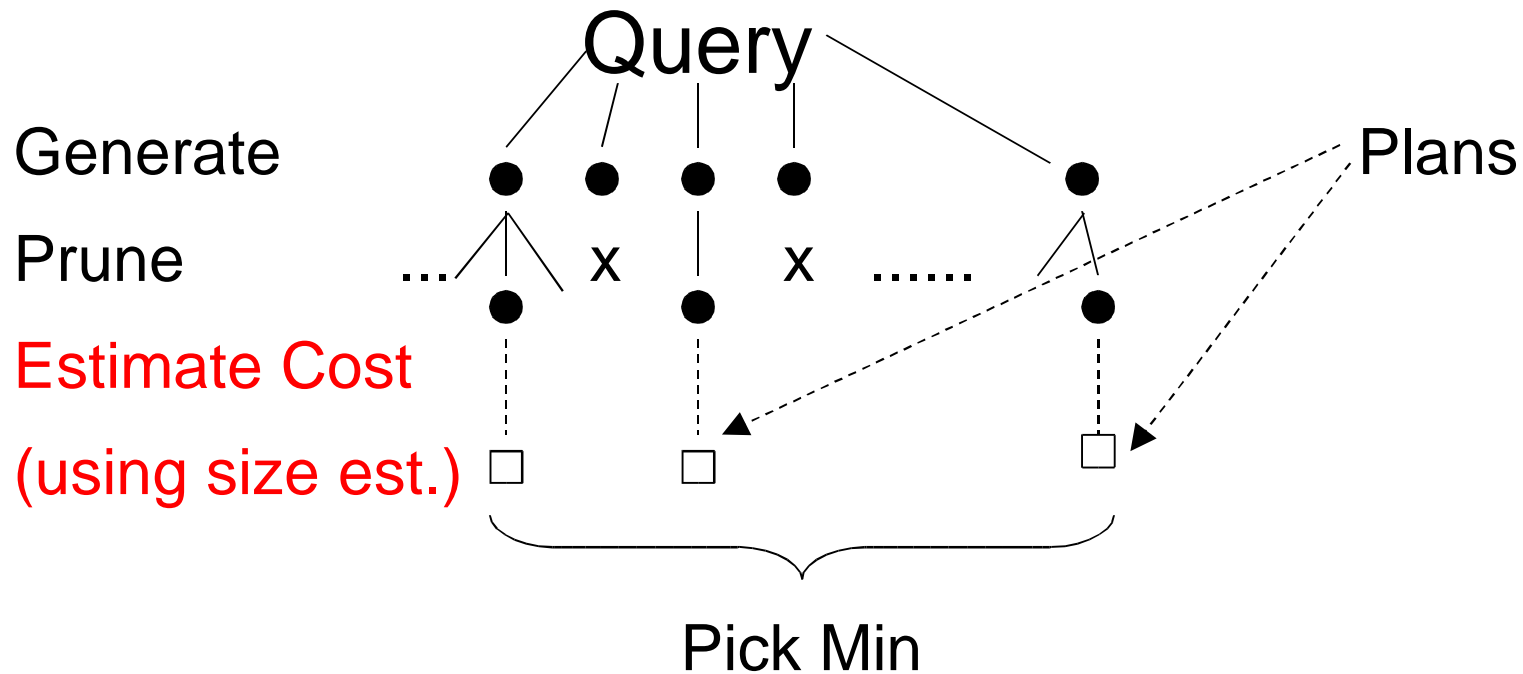
Maintaining statistics

- There is a cost to maintaining statistics.
- Book recommends recomputing "once in a while" (don't change rapidly).
- Recomputation may be operator-controlled.

Question: How does one compute the statistics ($V(R,A)$, histogram) of a relation?

Choosing a physical plan

Option 1: "Branch and bound".



Choosing a physical plan

Option 2: "Dynamic programming".

- Find best plans for subexpressions in bottom–up order.
- Might find several best plans:
 - The best plan that produces a sorted relation wrt. a later join or grouping attribute.
 - The best plan in general.

Choosing a physical plan

Options 3,4,...:

Other (heuristic) techniques from optimization.

- Greedy plan selection.
- Hill climbing.
- ...

Order for grouped operations

- Recall that we **grouped** commutative and associative operators, e.g.
 $R1 \square \rightarrow R2 \square \rightarrow R3 \square \rightarrow \dots \square \rightarrow Rk.$
- For such expressions we must choose an evaluation order (a parenthesized expression), e.g.
 $(R1 \square \rightarrow R4) \square \rightarrow (R3 \square \rightarrow \dots) \dots (\dots \square \rightarrow Rk).$

Order for grouped operations

- Book recommends considering just **left balanced** expressions
(...((R4 $\square \rightarrow$ R2) $\square \rightarrow$ R7) $\square \rightarrow$ ) $\square \rightarrow$ Rk.
- This gives **k!** possible expressions.
- Considering all possible expressions gives around **2^kk!** possibilities – not so many more.

Choosing final algorithms

- Usually best to use existing indexes.
- Sometimes building indexes or sorting on the fly is advantageous.
- Sorting based algorithms may beat hashing based algorithms if one of the relations is already sorted.
- Just do the calculation and see!

Pipelining and materialization

- Some algorithms (e.g. σ implemented as a scan) require little internal memory.
- **Idea:** Don't write result to disk, but feed it to the next algorithm immediately.
- Such **pipelining** may make many algorithms run "at the same time".
- Sometimes even possible with algorithms using more memory, such as sorting.

Summary

- **Size estimation** (using statistics) is an important part of query optimization.
- Given size estimates and a relational algebra expression, **query optimization** essentially consists of computing the (estimated) cost of all possible query plans.
- Other issues are **pipelining** and memory usage during execution.