Query Optimisation Tutorial

SWEN304/SWEN435

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Query Computation Costs for Unary Operators

- selection σ_C is linear in the size number n of tuples of the involved relation
  - scan the relation one tuple after the other
  - check for each tuple, whether the condition C is satisfied or not
  - keep exactly those tuples satisfying C
- projection π_{AL} is in $O(n \cdot \log n)$ with the number n of tuples
  - order the relation according to the attributes in AL
    (this is the most costly part leading to the complexity in $O(n \cdot \log n)$)
  - scan the relation one tuple after the other
  - project each tuple to the attributes in AL and check, whether result is the same as for previous tuple (duplicate elimination)
  - Note: SQL does not eliminate tuples, i.e. costs of projection are in $O(n)$, but `DISTINCT` needs the ordering
- renaming δ_f can be neglected

Query Computation Costs for Binary Operators

- join $\bowtie$ is in $O(n \cdot \log n)$ with $n = n_1 + n_2$, where n_i are the respective numbers of tuples in the two relations involved
  - the easiest idea is to use a nested loop:
    - scan the first relation one tuple after the other
    - for each tuple scan the second relation to find matching tuples, i.e., those coinciding with the given tuple on the common attributes
    - in case tuples match, take the joined tuple into the result relation
  - more efficient is the merge join:
    - sort both relations (this is the most costly part)
    - scan both relations simultaneously to find matching tuples
    - in case tuples match, take the joined tuple into the result relation
- union $\cup$ is in $O(n \cdot \log n)$ with $n = n_1 + n_2$, where n_i are the respective numbers of tuples in the two relations involved (analogously for difference $-$)
  - sort both relations as for the merge join
  - scan simultaneously to detect duplicates

Estimating the Size of Relations

- let $R = \{A_1, \ldots, A_k\}$ be a relation schema
- determine the size of a relation r over R:
  - let n denote the average number of tuples in the relation r
  - let ℓ_j denote the the average space (e.g., in bits) for attribute A_j in a tuple in r
  - then $\boxed{n \cdot \sum_{j=1}^{k} \ell_j}$ is the space needed for the relation r
- determine the size of intermediate relations in a query using the query tree:
  - assign the size of the relation to each leaf node R
  - for a renaming node the assigned size is exactly the size s assigned to the successor

Estimating the Size of Intermediate Results

- for a selection node σ_C the assigned size is $a_C \cdot s$, where s is the size assigned to the successor and $100 \cdot a_C$ is the average percentage of tuples satisfying C

- for a projection node π_{R_i} the assigned size is $(1 - C_i) \cdot s \cdot \frac{r_i}{r}$, where r_i (r) is the average size of a tuple in a relation over R_i (R), s is the size assigned to the successor and C_i is the probability that two tuples coincide on R_i
  $(1 - C_i) \cdot s \cdot \frac{r_i}{r} = (1 - C_i) \cdot n \cdot r_i$ where n is average number of tuples in R-relation

- for a join node the assigned size is $\frac{s_1}{r_1} \cdot p \cdot \frac{s_2}{r_2} \cdot (r_1 + r_2 - r)$, where s_i are the sizes of the successors, r_i are the corresponding tuple sizes, r is the size of a tuple over the common attributes and p is the matching probability

  Natural join needs to remove duplicate attributes
  For equi-join, r = 0

- for a union node the assigned size is $s_1 + s_2 - p \cdot s_1$ with the probability p for tuple of R_1 to coincide with a tuple over R_2

- for a difference node the assigned size is $s_1 \cdot (1 - p)$ where $(1 - p)$ is probability that tuple from R_1-relation does not occur as tuple in R_2-relation

Estimating the Size of Intermediate Results

- Person = {Name, Age, Address} with minimal key {Name, Address}
- Customer = {CustNo, CustName, CustAddress} with minimal key {CustNo} and foreign key [CustName, CustAddress] $\subseteq$ Person[Name, Address]

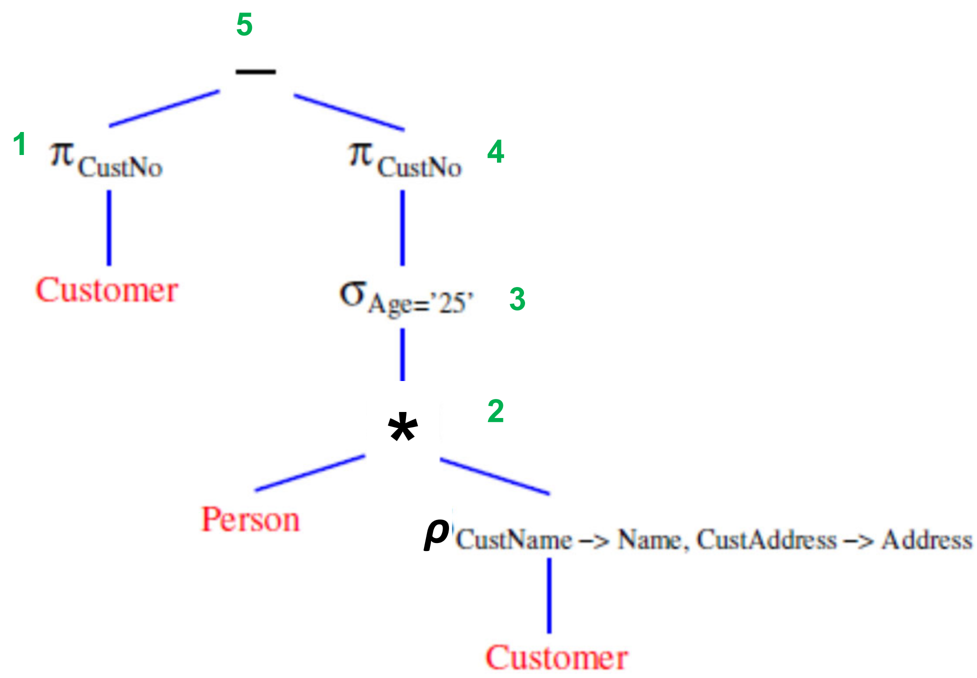
attribute	domain	average length
Name	VARCHAR(30)	15
Address	VARCHAR(50)	30
CustName	VARCHAR(30)	15
CustAddress	VARCHAR(50)	30

Assumptions

- Assume that the fixed number of bits for storing the age of a person is 8,
  - For values up to $2^8=256$
- assume to have 1000 customers in our database, and 1010 different people
- assume that there are exactly 5% of customers aged ‘25’, the value for a_c is 0.05,

Estimating the Size of Intermediate Results

- $\pi_{CustNo}(Customer) - \pi_{CustNo}(\sigma_{Age\ =\ '25'}(Person * \rho_{CustName \rightarrow Name, CustAddrss \rightarrow Address}(Customer)))$



Estimating the Size of Intermediate Results

- Compute the size of tuptle of **Customer**

  $r_{customer} = 15 \cdot 8 + 10 + 30 \cdot 8 = 370$ bits

- *Note*: we need 10 bits to store the customer number, if there are 1,000 customers ($2^{10} = 1, 024$)
- Average size of relation Customer

  $s_{customer} = 1, 000 \cdot 370 = 370, 000$ bits

- Computer the size of tuple **Person**

  $r_{person} = 15 \cdot 8 + 8 + 30 \cdot 8 = 368$ bits

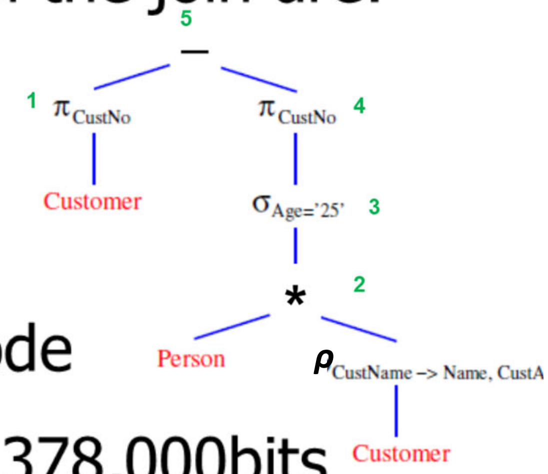
- Average size of a relation over Person:

  $s_{person} = 1, 010 \cdot 368 = 371, 680$ bits

Estimating the Size of Intermediate Results

- For the join node (**node 2**), the probability $p = \frac{1}{1010}$
- The attributes of the relation resulted from the join are:
- {Name, Address, Age, Customer}

  $r_2 = r_{Name} + r_{Address} + r_{Age} + r_{Customer}$
  $= 15 \cdot 8 + 30 \cdot 8 + 8 + 10 = 378$ bits



- Average size of the relation of the join node

$$S_2 = \frac{s_{person}}{r_{person}} \cdot \frac{1}{1010} \cdot \frac{s_{customer}}{r_{customer}} r_2 = 1000 \cdot 378 = 378{,}000 \text{bits}$$

- For selection node $\sigma_{Age = '25'}$ (**node 3**), $a_c = 5\%$

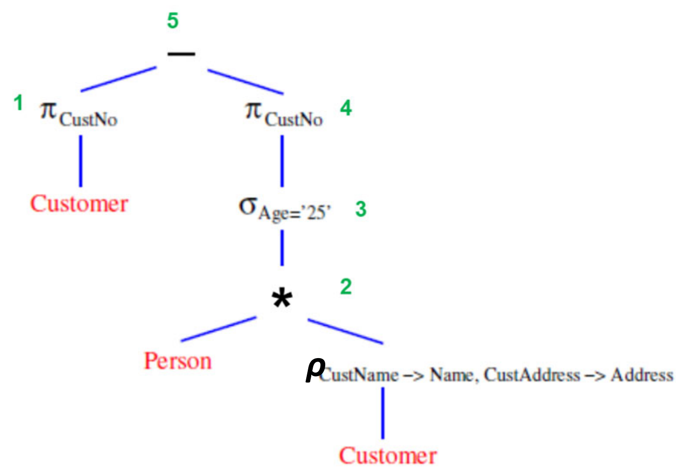
  $S_3 = 0.05 \cdot 378{,}000 = 18{,}900$ bits
- For project node π_{CustNo} (**node 4**), $C = 0\%$

  $s_4 = 18{,}900 \cdot 10/378 = 500$ bits

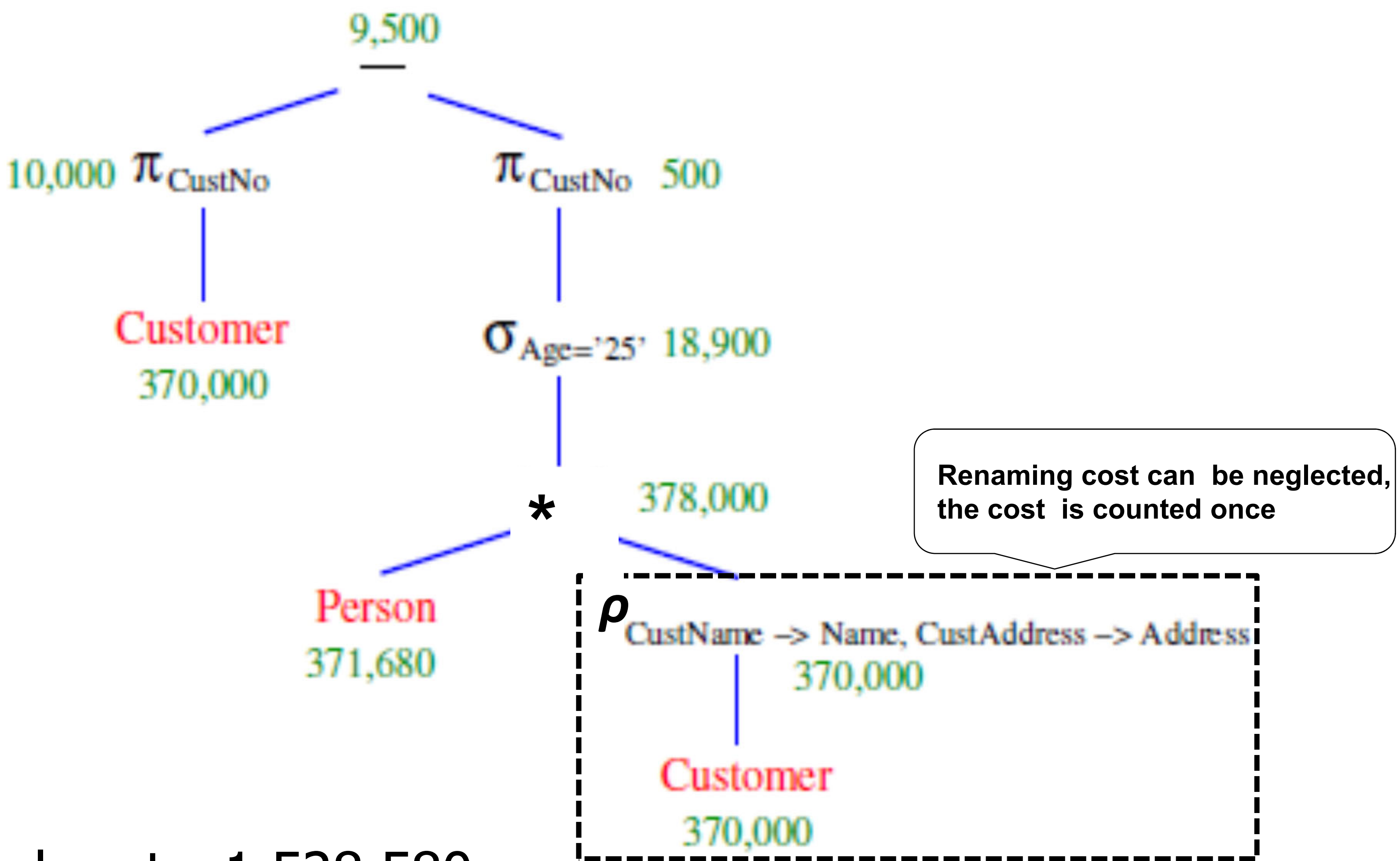
Estimating the Size of Intermediate Results

- For the projection π_{CustNo} (**node 1**), $C = 0\%$
  $s_1 = 370{,}000 \cdot 10/370 = 10{,}000$ bits

- For the difference (**node 5**), $p = 5\%$
  $s_5 = 10{,}000 \cdot (1 - 0.05) = 10{,}000 \cdot 0.95 = 9{,}500$ bits



Estimating the Size of Intermediate Results



- Total cost =1,528,580

Cost Related Catalog Content

- For the purpose of a query cost estimate, a Catalog should contain following information for each base relation:
  - Number of tuples (= records) n
  - Let n_s ($0 \leq n_s \leq n$) be the number of tuples that satisfy selection condition
  - Number of blocks b
  - Blocking factor f (= the number of tuples that fit into one block
  - Available access methods and access attributes:
    - Access methods: sequential, indexed, hashed
    - Access attributes: primary key, indexing attributes,
  - The number of levels h of each index
  - The number of distinct values d of each attribute

Cost Functions of Select Operation

- **Remark:**
  - **Linear search** (neither indexes nor hash functions provided)

    $$C = b + \lceil n_s / f \rceil \text{, hence } O(n)$$

    read write

  - **Unique key index** (B^+-tree):
    - If selection condition is $K = k$:

      $$C = h + 1 + \lceil 1 / f \rceil$$

      Hence $O(log\ n)$ – index height h is proportional to $log\ n$
    - If selection condition is $k_1 \leq K \leq k_2$ and suppose $n_s \leq n$ tuples satisfy the condition:

      $$C = h + \lceil n_s / m \rceil + n_s + \lceil n_s / f \rceil$$

      Hence $O(\max\{log\ n, n_s\})$

      the number of tree leaves containing key values $k_1 \leq K \leq k_2$

Cost Functions of Select Operation

- **Secondary index** (B^+-tree) on secondary key Y
  - $n_s \leq d(Y)$ random tuples satisfy condition $Y = y$
  - each Y value has a pointer to a sequence of blocks containing up to p pointers to tuples in the data area
  - the height h of the tree is proportional to $log(d(Y))$

$$C = h + \lceil n_s / p \rceil + n_s + \lceil n_s / f \rceil,$$

- Hence $O(n_s)$

Exercise

- Compute the total cost of the following query tree

- Person = {Name, Age, Address} with minimal key {Name, Address}
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$r_{customer} = 15 \cdot 8 + 10 + 30 \cdot 8 = 370$ bits

$r_{person} = 15 \cdot 8 + 8 + 30 \cdot 8 = 368$ bits

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