

Formal Query Languages: Relational Algebra

- ◆ Set Theory Operations
- ◆ Specific Relational Operations
- ◆ Write Queries in Relational Algebra



Relational Algebra $- + \times \div$

- Operations on entire relations
 - Operands are (constant or variable) relations
 - Result is a relation
- Set theory operations:
 - Union, Intersection, Difference and Cartesian Product (product for short)
- Specific relational operations:
 - Selection, Projection, Join and Division
- Complete set of relational algebra operations:
 - Select, project, product, union and difference
- SQL is based on concepts from relational algebra

Selection σ

- Unary operator Select, σ :

$\sigma_{\text{selection-condition}}(r)$

- E.g., $\sigma_{\text{Name} = \text{'John'} \vee \text{Name} = \text{'Susan'}}(\text{STUDENT})$
 - $\text{result} = \{t \mid t \in r \text{ and } (t[\text{Name}] = \text{'John'} \text{ or } t[\text{Name}] = \text{'Susan'})\}$
- *Selection condition* any logical expression on attributes of r involving any applicable comparison operator $\{=, <, \leq, >, \geq, \neq\}$

Example of Selection

- $\sigma_{\text{Name} = \text{'Bob'} \vee \text{Major} = \text{'Math'}}(S) = ?$

- $\sigma_{\text{Name} = \text{'Bob'} \wedge \text{Major} = \text{'Math'}}(S) = ?$

- How can I get a copy of S ?

- How can I get an empty copy of S ?

Relation S

SID	Name	Major
1	Bob	CS
3	Ann	CoE
4	Bob	Math

Projection

π

- Unary operator Project, π :

$\pi_{\text{Attribute-list}}(r)$

- Attribute-list $\subseteq R$

- E.g., $\pi_{\text{Name, Major}}(\text{STUDENT})$
 - result = $\{t \mid t \in r \text{ and } t[\text{Name, Major}]\}$

- What about $\pi_{\text{SID, Major}}(S) = ?$

Relation **S**

SID	Name	Major
1	Bob	CS
3	Ann	CoE
4	Bob	Math
5	Bob	CS

Relational Algebra Expressions

- Query: List the QPA of all students (SID) in CSD whose QPA is greater than 3.5

- STUDENT (SID, FName, SName, Dept, Major, QPA)

- Nesting** the operations

$\pi_{\text{SID, QPA}}(\sigma_{\text{Dept} = \text{'CSD'} \wedge \text{QPA} > 3.5}(\text{STUDENT}))$

- Sequence** of operations

$\text{HS} \leftarrow \sigma_{\text{Dept} = \text{'CSD'} \wedge \text{QPA} > 3.5}(\text{STUDENT})$

$\text{RESULT} \leftarrow \pi_{\text{SID, QPA}}(\text{HS})$

- Query tree**

- leaves nodes are relations and internal nodes are operations

Renaming Operator

- Renaming attributes of the result
 $\text{RSLT}(\text{StudentID, GPA}) \leftarrow \pi_{\text{SID, QPA}}(\text{HS})$

- Change the name of Attributes (in general):
 $\rho(a_1, a_2, a_3, \dots, a_n)(r)$

- Example:

$\rho(\text{StudentID, GPA}) (\pi_{\text{SID, QPA}}(\sigma_{\text{Dept} = \text{'CSD'} \wedge \text{QPA} > 3.5}(\text{STUDENT})))$

Properties of σ and π

$$\sigma_{\text{cond1}}(\sigma_{\text{cond2}}(R)) = \sigma_{\text{cond2}}(\sigma_{\text{cond1}}(R))$$

$$\begin{aligned} \sigma_{\text{cond1}}(\sigma_{\text{cond2}}(R)) &= \sigma_{\text{cond2} \wedge \text{cond1}}(R) \\ &= \sigma_{\text{cond1} \wedge \text{cond2}}(R) \end{aligned}$$

$$\pi_{\text{list1}}(\pi_{\text{list2}}(R)) = \pi_{\text{list1}}(R) \quad \text{When?}$$



Efficient / Optimized Queries

- ❑ Reduce cost of computing (a.k.a, *time-complexity*)
 - Short-circuit (fast computing logical expressions)
 - Execute faster comparisons first
- ❑ Reduce memory needs (a.k.a., *space-complexity*)
 - Execute Selections with high *selectivity* (i.e., with more strict conditions) to reduce the size of intermediate tables.
 - Execute Projects as early as possible to reduce tuple size

Selectivity

- ❑ Selectivity = The **ratio** of the number of records that satisfy a condition to the total number of records
- ❑ Let assume that Students
 - Female = 55% & Male 45%
 - CS majors = 5% & Non-CS majors = 95%
- ❑ Which is more efficient?
 - $\sigma_{\text{Major} = \text{'Non-CS'} \wedge \text{Gender} = \text{'Female'}}(\text{STUDENT})$
 - $\sigma_{\text{Gender} = \text{'Female'} \wedge \text{Major} = \text{'Non-CS'}}(\text{STUDENT})$
 - $\sigma_{\text{Major} = \text{'CS'} \wedge \text{Gender} = \text{'Female'}}(\text{STUDENT})$