Relational Query Languages

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- *Query languages:* Allow manipulation and retrieval of data from a database.
- Relational model supports simple, powerful QLs:
  - Formal foundation based on logic.
  - Allows for optimization.
- Query Languages != programming languages!
  - QLs not intended to be used for complex calculations.
  - QLs support easy, efficient access to large data sets.

Credit: R. Ramakrishnan, J. Gehrke

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DBMS Architecture

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How does a SQL engine work ?

- SQL query → relational algebra plan
- Relational algebra plan → Optimized plan
- Execute each operator of the plan

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Relational Algebra

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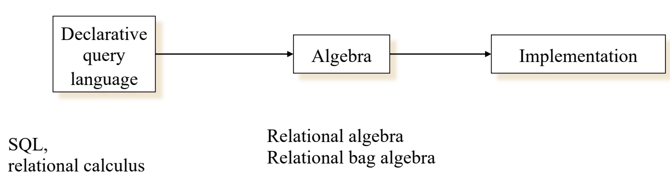
- Formalism for creating new relations from existing ones
- Its place in the big picture:



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Formal Relational Query Languages

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Two mathematical Query Languages form the basis for SQL, and for implementation:

- *Relational Algebra:* More operational, very useful for representing execution plans.
- *Relational Calculus:* Lets users describe what they want, rather than how to compute it. (Non-operational, *declarative*.)

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What is an "Algebra"

- Mathematical system consisting of:
  - *Operands* --- variables or values from which new values can be constructed.
  - *Operators* --- symbols denoting procedures that construct new values from given values.

Credit: Renee J. Miller

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What is Relational Algebra?

- An algebra whose operands are relations or variables that represent relations.
- Operators are designed to do the most common things that we need to do with relations in a database.
  - The result is an algebra that can be used as a *query language* for relations.

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Core Relational Algebra

- Union, intersection, and difference.
  - Usual operations, but *both operands must have the same relation schema*.
- Selection: picking certain rows.
- Projection: picking certain columns.
- Products and joins: compositions of relations.
- Renaming of relations and attributes.

Since each operation returns a relation, *operations can be composed*

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Selection

- R1 := σ_C (R2)
  - C is a condition (as in "if" statements) that refers to attributes of R2.
  - R1 is all those tuples of R2 that satisfy C.

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Example: Selection

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Relation Sells:

bar	beer	price
Joe's	Bud	2.50
Joe's	Miller	2.75
Sue's	Bud	2.50
Sue's	Miller	3.00

JoeMenu := $\sigma_{bar=\text{"Joe's"}}$(Sells):

bar	beer	price
Joe's	Bud	2.50
Joe's	Miller	2.75

- Selects rows that satisfy *selection condition.*
- *Schema* of result identical to schema of (only) input relation.
- *Result* relation can be the *input* for another relational algebra operation. (*Operator composition.*)

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Projection

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- R1 := π_L (R2)
  - *L* is a list of attributes from the schema of R2.
  - R1 is constructed by looking at each tuple of R2, extracting the attributes on list *L*, in the order specified, and creating from those components a tuple for R1.

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Example: Projection

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Relation Sells:

bar	beer	price
Joe's	Bud	2.50
Joe's	Miller	2.75
Sue's	Bud	2.50
Sue's	Miller	3.00

Prices := $\pi_{beer,price}$(Sells):

beer	price
Bud	2.50
Bud	2.50
Miller	2.75
Miller	3.00

Schema of result contains exactly the fields in the projection list, with the same names that they had in the (only) input relation.

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Example

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Relation Sells:

bar	beer	price
Joe's	Bud	2.50
Joe's	Miller	2.75
Sue's	Bud	2.50
Sue's	Miller	3.00

JoePrices := $\pi_{beer,price}(\sigma_{bar=\text{"Joe's"}}(Sells))$

Beer	Price
Bud	2.50
Miller	2.75

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Extended Projection

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- Using the same π_L operator, we allow the list L to contain arbitrary expressions involving attributes:
  - Arithmetic on attributes, e.g., $A+B \rightarrow C$.

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Example: Extended Projection

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R =

A	B
1	2
3	4

$\pi_{A+B \rightarrow C, A \rightarrow A1, A \rightarrow A2}$ (R) =

C	A1	A2
3	1	1
7	3	3

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Product

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- R3 := R1 X R2
  - Pair each tuple t1 of R1 with each tuple t2 of R2.
  - Concatenation t1t2 is a tuple of R3.
  - Schema of R3 is the attributes of R1 and then R2, in order.
  - But beware attribute *A* of the same name in R1 and R2:
    - In relational algebra use renaming to distinguish
    - in SQL use R1.*A* and R2.*A*.

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Example: R3 := R1 X R2

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R1(

A	B
1	2
3	4

)

R2(

B	C
5	6
7	8
9	10

)

R3(

A,	R1.B,	R2.B,	C
1	2	5	6
1	2	7	8
1	2	9	10
3	4	5	6
3	4	7	8
3	4	9	10

)

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Theta-Join

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- R3 := R1 $\bowtie_C$ R2
  - Take the product R1 X R2.
  - Then apply σ_C to the result.
- As for σ_C can be any boolean-valued condition.
  - A θ B, where θ is =, <, etc.; hence the name "theta-join."

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Example: Theta Join

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Sells(

bar,	beer,	price)
Joe's	Bud	2.50
Joe's	Miller	2.75
Sue's	Bud	2.50
Sue's	Coors	3.00

Bars(

name,	addr)
Joe's	Maple St.
Sue's	River Rd.

BarInfo := Sells $\bowtie_{Sells.bar\ =\ Bars.name}$ Bars

BarInfo(

bar,	beer,	price,	name,	addr)
Joe's	Bud	2.50	Joe's	Maple St.
Joe's	Miller	2.75	Joe's	Maple St.
Sue's	Bud	2.50	Sue's	River Rd.
Sue's	Coors	3.00	Sue's	River Rd.

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Natural Join

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- A useful join variant (*natural* join) connects two relations by:
  - Equating attributes of the same name, and
  - Projecting out one copy of each pair of equated attributes.
- Denoted R3 := R1 $\bowtie$ R2.

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Example: Natural Join

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Sells(

bar,	beer,	price)
Joe's	Bud	2.50
Joe's	Miller	2.75
Sue's	Bud	2.50
Sue's	Coors	3.00

Bars(

bar,	addr)
Joe's	Maple St.
Sue's	River Rd.

BarInfo := Sells $\bowtie$ Bars

Note: Bars.name has become Bars.bar to make the natural join non-trivial

BarInfo(

bar,	beer,	price,	addr)
Joe's	Bud	2.50	Maple St.
Joe's	Milller	2.75	Maple St.
Sue's	Bud	2.50	River Rd.
Sue's	Coors	3.00	River Rd.

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Renaming

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- The ρ operator gives a new schema to a relation.
- R1 := $\rho_{R1(A1,\ldots,An)}$(R2) makes R1 be a relation with attributes A1,…,An and the same tuples as R2.
- Simplified notation: R1(A1,…,An) := R2.

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Example: Renaming

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Bars(

name,	addr
Joe's Sue's	Maple St. River Rd.

)

R(bar, addr) := Bars

R(

bar,	addr
Joe's Sue's	Maple St. River Rd.

)

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