# Relational Calculus and Query-By-Example

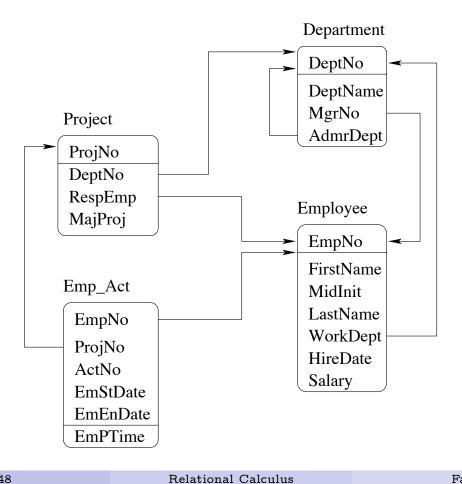
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CS 348 Introduction to Database Management Fall 2012

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# Database Schema Used in Examples



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### Relational Calculus

#### Idea

Use first-order logic (FOL) formulae to specify properties of the query answer.

### Vocabulary:

- set of constants
- set of variables
- set of comparison predicates (=, <, ...)
- set of *n*-ary predicates
- set of *n*-ary functions
- logical connectives  $(\land, \lor, \neg, \Rightarrow)$
- quantifiers:  $\exists$ ,  $\forall$
- parentheses

Expressions (called well formed formulae (wff)) built from this vocabulary.

	vocabulary.		
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### Relational Calculus: Semantics

How do we interpret variables?

### Definition (Valuation)

A *valuation* is a mapping from *variable names* to values in the universe.

#### Idea

Answers to a query



Valuations for free variables that make the query formula true with respect to a database.

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# Types of Relational Calculus

According to the primitive variable used in specifying the queries:

- tuple relational calculus
- domain relational calculus

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## Tuple Relational Calculus

TRC formulae are built using:

Conjunctive

- $x_i \in R$  (atomic)
  - $x_i.a \ op \ x_j.b$  (atomic)
  - $x_i.a$  op c (atomic)
  - $\varphi \wedge \psi$
  - ullet  $\exists x_i(arphi)$

Positive •  $\varphi \lor \psi$ 

First-order  $\bullet \neg \varphi$ 

- $\varphi \Rightarrow \psi$  (redundant)
- $\forall x_i(\varphi)$  (redundant)

#### Note

A well-formed TRC query should contain only one free variable.

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## Tuple Relational Calculus: Example

• Find the last names and hire dates of employees who make more than \$100000.

DRC:

$$egin{array}{lll} \{\langle N,D
angle & \exists S ( ext{Employee}\langle\_,\_,\_,N,\_,D,S
angle \ & \land S > 100000) \} \end{array}$$

TRC:

$$egin{array}{lll} \{ W & | & \exists E(E \in ext{Employee} \land W.lastname = E.lastname \ & \land W.hiredate = E.hiredate \ & \land E.salary > 100000) \} \end{array}$$

or

$$\{W \mid \exists E \in ext{Employee}(W.lastname = E.lastname \ \ \land W.hiredate = E.hiredate \ \ \land E.salary > 100000)\}$$

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### Domain Relational Calculus

DRC formulae are built using:

ullet  $R\langle x_{i_1},\ldots,x_{i_k}
angle$  (atomic) Conjunctive

•  $x_i$  op  $x_j$  (atomic)

•  $x_i$  op c (atomic)

•  $\varphi \wedge \psi$ 

ullet  $\exists x_i(arphi)$ 

Positive •  $\varphi \lor \psi$ 

First-order  $\bullet \neg \varphi$ 

•  $\varphi \Rightarrow \psi$  (redundant)

•  $\forall x_i(\varphi)$  (redundant)

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## Domain Relational Calculus: Example

• Find the last names and hire dates of employees who make more than \$100000.

$$\{\langle N,D \rangle \mid \exists E,F,M,W,S ( ext{Employee} \langle E,F,M,N,W,D,S \rangle \\ \land S > 100000) \}$$

or

$$\{\langle N,D
angle \mid \exists E,F,M,W,S(\langle E,F,M,N,W,D,S
angle \in ext{Employee} \ \land S>100000)\}$$

or

$$\{\langle N, D \rangle \mid \exists S (\text{Employee} \langle \_, \_, \_, N, \_, D, S \rangle \land S > 100000) \}$$

or

$$\{\langle N,D \rangle \mid \exists S(\langle \_,\_,\_,N,\_,D,S \rangle \in \operatorname{Employee} \land S > 100000)\}$$

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## Safety of Relational Calculus Formulae

• Find all dates on which no employee was hired.

$$\{\langle D \rangle \mid \neg \text{Employee} \langle \_, \_, \_, \_, \_, D, \_ \rangle \}$$

#### Problem

The answer to this query is not finite (assuming D's domain is not finite).

### Definition (Safety)

A query is *safe* if, for all databases instances conforming to the schema, the query result can be computed using only constants appearing in the database instance or in the query itself.

As long as the database instance is finite, the result of any safe query will also be finite.

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## Safety – Examples

• employees who are active in all projects:

```
egin{array}{lll} \{\langle E 
angle & | & Employee \langle E, \ldots 
angle \ & \land orall P(Project \langle P, \ldots 
angle 
ightarrow EmpAct \langle E, P, \ldots 
angle) \} \end{array}
```

• departments that hire employees every day:

$$\{\langle D \rangle \mid Department \langle D, \ldots \rangle \\ \land \forall H(Employee \langle \ldots, D, H, \_ \rangle)\}$$

Safe?

Safe?

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### Query-By-Example

- QBE: a graphical language heavily influenced by DRC
  - QBE is an IBM trademark
  - influenced Paradox, Access, other end-user query tools
  - convenient for simple queries
  - awkward for complex queries
- Language basics:
  - query composed of relation "skeletons"
  - output attributes marked with "P." (single skeleton only)
  - variables used for equality predicates
  - atomic conditions placed below attribute, or in CONDITIONS box
  - multiple rows in a skeleton means OR
  - skeletons can be negated, but variables appearing in negated skeleton must also appear in positive skeleton

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# QBE: Example

• Find the last names and hire dates of employees who make more than \$100000.

DRC:

$$egin{array}{lll} \{\langle N,D 
angle & \exists S ( ext{Employee} \langle \_,\_,\_,N,\_,D,S 
angle \\ & \land S > 100000) \} \end{array}$$

QBE:

Employee	ENo	FName	MInit	LName	Dept	HDate	Sal
				Р.		Р.	>100000

or

Employee	ENo	FName	MInit	LName	Dept	HDate	Sal
				P.		P.	_S
CONDITIONS			ONS				
			_S > 100000				

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# QBE: Another Example

• For each project for which department E21 is responsible, find the name of the employee in charge of that project.

DRC:

QBE:

Project	PNo	Dept	RespEmp	MajProj		
	P.	'E21'	_E		P.	_N

Employee	ENo	FName	MInit	LName	Dept	HDate	Sal
	_E			_N			

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