Relational Calculus

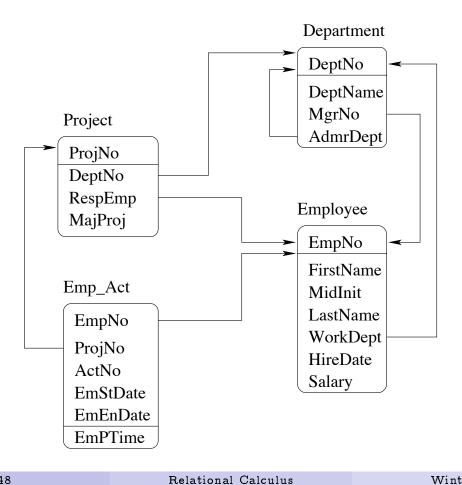
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CS 348 Introduction to Database Management Winter 2013

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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.

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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:

- - $x_i.a$ 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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Votes				

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:

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

or

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

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Domain Relational Calculus

DRC formulae are built using:

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

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

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

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

or

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

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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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