Topic 6:

Relational Calculi

Meanings of ‘Calculus’

- Calculus refers to any method or system of calculation
- ‘Calculus’ is derived from the Latin word for ‘pebble.’
- Modern uses of the word include:
  - Differential Calculus: instantaneous rates of change
  - Integral Calculus: limits of sums of terms
  - Lambda Calculus: functional abstraction & application
  - Predicate Calculus: reasoning about symbolic logic

Review of First–Order Predicate Calculus (FOPC) (1 / 2)

Why? Because FOPC $\Rightarrow$ Relational Calculus $\Rightarrow$ SQL

FOPC (a.k.a. First–Order Logic):

- Uses statements of the form "$P(x)$", where P is a predicate and x is a subject
- In FOPC, subjects may be values; they may not be predicates (see: Second-Order Logic)
- FOPC can formalize all of set theory
  - Recall that the Relational Model is based on set theory

Review of First–Order Predicate Calculus (FOPC) (2 / 2)

Supplied Primitives Include:

Variables, Logical Operators, Quantifiers, . . .

Constructs of Our Creation Include:

Constants, Predicates, Functions (e.g. n^2), . . .

Example(s):

Assume: Feathers(x): x has feathers, $x \in$ Animals
Bird(x): x is a bird, $x \in$ Animals

Relational Calculi: Ideas

Relational Calculi are “what, not how” languages

There are two forms, each with the same expressive power:

Tuple Relational Calculus: Background (1 / 2)

- Proposed by Codd in 1972
- Abbreviated as “TRC”
- So named because the variables in TRC represent tuples
- TRC queries have this basic form:

where:

Tuple Relational Calculus: Background (2 / 2)

Where are quantifiers ($\exists$ and/or $\forall$) used in Rel. Calc.?

- We quantify (bind) all tuple variables that do not appear on the left of the 'such that' ($\mid$) symbol
- Most queries only use $\exists$ (because most queries are asking if appropriate data *exists* in the DB)
- $\forall$ is used for "find X that are matched with all Y" queries
  - We will avoid such queries in relational calculus

    (Why? In Rel. Calc., they're really messy.)
  - But we will deal with them in upcoming languages!

TRC: Query #1

Question: What is the content of the Employee Relation?

Recall these schemas:

DEPARTMENT	DeptNum	DeptName	ManagerID	ManagerStartDate	
EMPLOYEE	Surname	GivenName	EmpNum	DeptID	Salary

TRC: Query #2

Question: What are the names and salaries of the people in department #5?

DEPARTMENT	DeptNum	DeptName	ManagerID	ManagerStartDate
EMPLOYEE	Surname	GivenName	EmpNum	DeptID	Salary

TRC: Query #3

Question: What are the names of the parts that can be supplied by individual suppliers in quantity > 200?

S	S#	Sname	Status	City	
P	P#	Pname	Color	Weight	City
SP	S#	P#	Qty		

TRC: Query #4

Question: What are the names of the active suppliers of nuts?

S	S#	Sname	Status	City
P	P#	Pname	Color	Weight	City
SP	S#	P#	Qty	

Aside: Expression Safety

Definition: Expression Safety

Example(s):

Domain Relational Calculus (DRC): Bkgd.

- Proposed by Lacroix and Pirotte in 1977 to supply a formalism for IBM's Query By Example (QBE) product.
- In DRC, a variable represents just one field of a tuple
- DRC queries have this basic form:

where:

DRC Query #1

Question: What is the content of the Employee Relation?

Note the helpful field labels! ⇓

	a	b	c	d
DEPARTMENT	DeptNum	DeptName	ManagerID	ManagerStartDate

	e	f	g	h	i
EMPLOYEE	Surname	GivenName	EmpNum	DeptID	Salary

DRC Query #2

Question: What are the names and salaries of the people in department #5?

	a	b	c	d
DEPARTMENT	DeptNum	DeptName	ManagerID	ManagerStartDate

	e	f	g	h	i
EMPLOYEE	Surname	GivenName	EmpNum	DeptID	Salary

DRC Query #3

Question: What are the names of the parts that can be supplied by individual suppliers in quantity > 200?

	j	k	l	m
S	S#	Sname	Status	City

	n	o	p	q	r
P	P#	Pname	Color	Weight	City

	s	t	u
SP	S#	P#	Qty

DRC Query #4 (1 / 2)

Question: **What are the names of the active suppliers of nuts?**

	j	k	l	m
S	S#	Sname	Status	City

	n	o	p	q	r
P	P#	Pname	Color	Weight	City

	s	t	u
SP	S#	P#	Qty

DRC Query #4 (2 / 2) — Alternate Join Option

Question: **What are the names of the active suppliers of nuts?**

$$\{ < k > \mid (\exists jl)(< jklm > \in \text{S} \ \wedge \ l > 0 \ \wedge$$
$$(\exists t)(< \boxed{\text{j}} tu > \in \text{SP} \ \boxed{\cancel{\wedge \ s = j}} \ \wedge$$
$$(\exists o)(< \boxed{\text{t}} opqr > \in \text{P} \ \boxed{\cancel{\wedge \ t = n}} \ \wedge \ o = \text{'Nut'})))\}$$

(We copied vars and eliminated the corresponding conditions.)

	j	k	l	m
S	S#	Sname	Status	City

	n	o	p	q	r
P	P#	Pname	Color	Weight	City

	s	t	u
SP	S#	P#	Qty