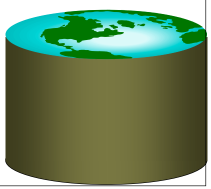
The Relational Model

CS 186, Fall 2005, Lecture 2

R & G, Chap. 3



Review

- Why use a DBMS? OS provides RAM and disk

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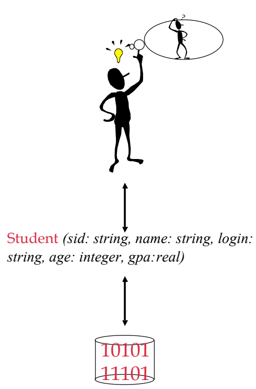
- Why use a DBMS? OS provides RAM and disk
  - Concurrency
  - Recovery
  - Abstraction, Data Independence
  - Query Languages
  - Efficiency (for most tasks)
  - Security
  - Data Integrity

Glossary

- Byte
- Kilobyte: 2^10 B
- Megabyte: 2^20 B
- Gigabyte: 2^30 B
- Terabyte: 2^40 B
  - Typical video store has about 8 TB
  - Library of Congress is about 20TB
  - Costs you about $500 at PCConnection, will hold your family videos
- Petabyte: 2^50 B
  - Internet Archive WayBack Machine is now about 2 PetaByte
- Exabyte: 2^60 B
  - Total amount of printed material in the world is 5 Exabytes
- Zettabyte: 2^70 B
- Yottabyte: 2^80 B

Data Models

- DBMS models real world
- *Data Model* is link between user's view of the world and bits stored in computer
- Many models exist
- We will concentrate on the Relational Model



Why Study the Relational Model?

- Most widely used model.
- "Legacy systems" in older models
  - e.g., IBM's IMS
- Object-oriented concepts merged in
  - "Object-Relational" model
    - Early work done in POSTGRES research project at Berkeley
- XML features in most relational systems
  - Can export XML interfaces
  - Can embed XML inside relational fields

Relational Database: Definitions

- Relational database: a set of relations.
- Relation: made up of 2 parts:
  - Schema : specifies name of relation, plus name and type of each column.
    - E.g. Students(sid: string, name: string, login: string, age: integer, gpa: real)
  - Instance : a table, with rows and columns.
    - #rows = cardinality
    - #fields = degree / arity
- Can think of a relation as a set of rows or tuples.
  - i.e., all rows are distinct

Ex: Instance of Students Relation

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

- Cardinality = 3, arity = 5 , all rows distinct
- Do all values in each column of a relation instance have to be distinct?

SQL - A language for Relational DBs

- SQL (a.k.a. "Sequel"), standard language
- Data Definition Language (DDL)
  - create, modify, delete relations
  - specify constraints
  - administer users, security, etc.
- Data Manipulation Language (DML)
  - Specify queries to find tuples that satisfy criteria
  - add, modify, remove tuples

SQL Overview

- CREATE TABLE <name> (<field> <domain>, …)
- INSERT INTO <name> (<field names>)
VALUES (<field values>)
- DELETE FROM <name>
WHERE <condition>
- UPDATE <name>
SET <field name> = <value>
WHERE <condition>
- SELECT <fields>
FROM <name>
WHERE <condition>

Creating Relations in SQL

- Creates the Students relation.
  - Note: the type (domain) of each field is specified, and enforced by the DBMS whenever tuples are added or modified.

```
CREATE TABLE Students
    (sid CHAR(20),
     name CHAR(20),
     login CHAR(10),
     age INTEGER,
     gpa FLOAT)
```

Table Creation (continued)

- Another example: the Enrolled table holds information about courses students take.

```
CREATE TABLE Enrolled
    (sid CHAR(20),
     cid CHAR(20),
     grade CHAR(2))
```

Adding and Deleting Tuples

- Can insert a single tuple using:

```
INSERT INTO Students (sid, name, login, age, gpa)
 VALUES  ('53688', 'Smith', 'smith@ee', 18, 3.2)
```

- **Can delete all tuples satisfying some condition (e.g., name = Smith):**

```
DELETE
 FROM Students S
 WHERE S.name = 'Smith'
```

Powerful variants of these commands are available; more later!

Keys

- Keys are a way to associate tuples in different relations
- Keys are one form of integrity constraint (IC)

Enrolled

sid	cid	grade
53666	Carnatic101	C
53666	Reggae203	B
53650	Topology112	A
53666	History105	B

Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

FOREIGN Key

PRIMARY Key

Primary Keys

- A set of fields is a superkey if:
  - No two distinct tuples can have same values in all key fields
- A set of fields is a key for a relation if :
  - It is a superkey
  - No subset of the fields is a superkey
- what if >1 key for a relation?
  - One of the keys is chosen (by DBA) to be the primary key. Other keys are called candidate keys.
- E.g.
  - sid is a key for Students.
  - What about name?
  - The set {sid, gpa} is a superkey.

Primary and Candidate Keys in SQL

- Possibly many *candidate keys* (specified using UNIQUE), one of which is chosen as the *primary key*.
- Keys must be used carefully!
- "For a given student and course, there is a single grade."

```
CREATE TABLE Enrolled
 (sid CHAR(20)
  cid  CHAR(20),
  grade CHAR(2),
  PRIMARY KEY (sid,cid))
```

vs.

```
CREATE TABLE Enrolled
  (sid CHAR(20)
   cid  CHAR(20),
   grade CHAR(2),
   PRIMARY KEY  (sid),
   UNIQUE (cid, grade))
```

"Students can take only one course, and no two students in a course receive the same grade."

Foreign Keys, Referential Integrity

- *Foreign key*: Set of fields in one relation that is used to `refer' to a tuple in another relation.
  - Must correspond to the primary key of the other relation.
  - Like a `logical pointer'.
- If all foreign key constraints are enforced, *referential integrity* is achieved (i.e., no dangling references.)

Foreign Keys in SQL

- **E.g. Only students listed in the Students relation should be allowed to enroll for courses.**
  - *sid* is a foreign key referring to Students:

```
CREATE TABLE Enrolled
(sid CHAR(20),cid CHAR(20),grade CHAR(2),
 PRIMARY KEY (sid,cid),
 FOREIGN KEY (sid) REFERENCES Students )
```

Enrolled

sid	cid	grade
53666	Carnatic101	C
53666	Reggae203	B
53650	Topology112	A
53666	History105	B
~~11111~~	~~English102~~	~~A~~

Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

Enforcing Referential Integrity

- Consider Students and Enrolled; *sid* in Enrolled is a foreign key that references Students.
- What should be done if an Enrolled tuple with a non-existent student id is inserted? (*Reject it!*)
- What should be done if a Students tuple is deleted?
  - Also delete all Enrolled tuples that refer to it?
  - Disallow deletion of a Students tuple that is referred to?
  - Set sid in Enrolled tuples that refer to it to a *default sid*?
  - (In SQL, also: Set sid in Enrolled tuples that refer to it to a special value *null*, denoting `*unknown*' or `*inapplicable*'.)
- Similar issues arise if primary key of Students tuple is updated.

Integrity Constraints (ICs)

- IC: condition that must be true for *any* instance of the database; e.g., *domain constraints.*
  - ICs are specified when schema is defined.
  - ICs are checked when relations are modified.
- A *legal* instance of a relation is one that satisfies all specified ICs.
  - DBMS should not allow illegal instances.
- If the DBMS checks ICs, stored data is more faithful to real-world meaning.
  - Avoids data entry errors, too!

Where do ICs Come From?

- ICs are based upon the semantics of the real-world that is being described in the database relations.
- We can check a database instance to see if an IC is violated, but we can NEVER infer that an IC is true by looking at an instance.
  - An IC is a statement about all possible instances!
  - From example, we know name is not a key, but the assertion that sid is a key is given to us.
- Key and foreign key ICs are the most common; more general ICs supported too.

Administrivia

- Web page and Syllabus are (mostly) on-line
  - Schedule and due dates may change (check frequently)
  - Lecture notes are/will be posted
  - Homework/project details to be posted
- HW 0 posted -- due Monday midnight!
  - Accts forms!
- Other textbooks
  - Korth/Silberschatz/Sudarshan
  - O'Neil and O'Neil
  - Garcia-Molina/Ullman/Widom

Relational Query Languages

- A major strength of the relational model: supports simple, powerful *querying* of data.
- Queries can be written intuitively, and the DBMS is responsible for efficient evaluation.
  - The key: precise semantics for relational queries.
  - Allows the optimizer to extensively re-order operations, and still ensure that the answer does not change.

The SQL Query Language

- The most widely used relational query language.
  - Current std is SQL:2003; SQL92 is a basic subset
- To find all 18 year old students, we can write:

```
SELECT *
FROM Students S
WHERE S.age=18
```

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@ee	18	3.2

- To find just names and logins, replace the first line:

```
SELECT S.name, S.login
```

Querying Multiple Relations

- What does the following query compute?

```
SELECT S.name, E.cid
 FROM Students S, Enrolled E
 WHERE S.sid=E.sid AND E.grade='A'
```

Given the following instance of Enrolled

sid	cid	grade
53831	Carnatic101	C
53831	Reggae203	B
53650	Topology112	A
53666	History105	B

we get:

S.name	E.cid
Smith	Topology112

Semantics of a Query

- A *conceptual evaluation method* for the previous query:
  1. do FROM clause: compute *cross-product* of Students and Enrolled
  2. do WHERE clause: Check conditions, discard tuples that fail
  3. do SELECT clause: Delete unwanted fields
- Remember, this is *conceptual*. Actual evaluation will be *much* more efficient, but must produce the same answers.

Cross-product of Students and Enrolled Instances

S.sid	S.name	S.login	S.age	S.gpa	E.sid	E.cid	E.grade
53666	Jones	jones@cs	18	3.4	53831	Carnatic101	C
53666	Jones	jones@cs	18	3.4	53832	Reggae203	B
53666	Jones	jones@cs	18	3.4	53650	Topology112	A
53666	Jones	jones@cs	18	3.4	53666	History105	B
53688	Smith	smith@ee	18	3.2	53831	Carnatic101	C
53688	Smith	smith@ee	18	3.2	53831	Reggae203	B
53688	Smith	smith@ee	18	3.2	53650	Topology112	A
53688	Smith	smith@ee	18	3.2	53666	History105	B
53650	Smith	smith@math	19	3.8	53831	Carnatic101	C
53650	Smith	smith@math	19	3.8	53831	Reggae203	B
53650	Smith	smith@math	19	3.8	**53650**	Topology112	**A**
53650	Smith	smith@math	19	3.8	53666	History105	B

Relational Model: Summary

- A tabular representation of data.
- Simple and intuitive, currently the most widely used
  - Object-relational variant gaining ground
  - XML support added in SQL:2003, most systems
- Integrity constraints can be specified by the DBA, based on application semantics. DBMS checks for violations.
  - Two important ICs: primary and foreign keys
  - In addition, we always have domain constraints.
- Powerful query languages exist.
  - SQL is the standard commercial one
    - DDL - Data Definition Language
    - DML - Data Manipulation Language