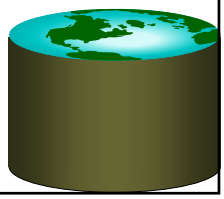
The Relational Model

CS 186, Spring 2006, Lecture 2
R & G, Chap. 1 & 3



Administrivia I

- **CS 186 IS MOVING!!!!**
- **Starting TUES 1/24 (next week) we will be in 105 NORTHGATE**

Administrivia II

- Recall: Discussion Sections
  - W11-12 70 Evans
  - W 2-3 70 Evans
  - W 3-4 241 Cory
- Section on Tuesdays is Cancelled.
- Still working on approval for 3rd TA.
- Web site is getting there.
- Details on Projects, Grading, TA office hours, etc. available by Tuesday.
- I *will* be holidng office hours today as scheduled: 1-2pm 687 Soda Hall

Administrivia III - Don't Forget

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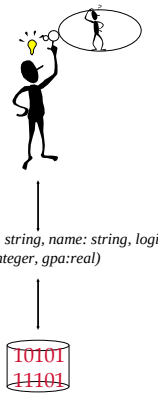
Data Models

- **A Database models some portion of the real world.**
- ***Data Model* is link between user's view of the world and bits stored in computer.**
- **Many models have been proposed.**
- **We will concentrate on the Relational Model.**

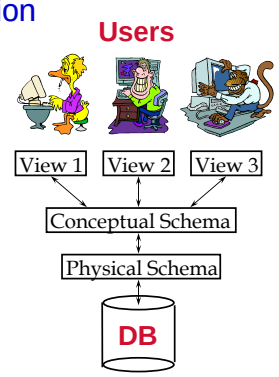


Describing Data: Data Models

- **A *data model* is a collection of concepts for describing data.**
- **A database *schema* is a description of a particular collection of data, using a given data model.**
- **The *relational model of data* is the most widely used model today.**
  - Main concept: *relation*, basically a table with rows and columns.
  - Every relation has a *schema*, which describes the columns, or fields.

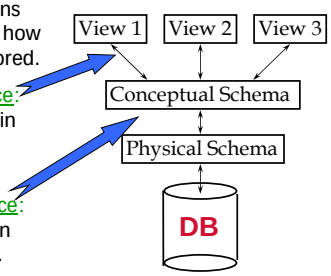
Levels of Abstraction

- Views describe how users see the data.
- Conceptual schema defines logical structure
- Physical schema describes the files and indexes used.
- (sometimes called the ANSI/SPARC model)



Data Independence: The Big Breakthrough of the Relational Model

- A Simple Idea: Applications should be insulated from how data is structured and stored.
- Logical data independence: Protection from changes in *logical* structure of data.
- Physical data independence: Protection from changes in *physical* structure of data.



- Q: Why are these particularly important for DBMS?

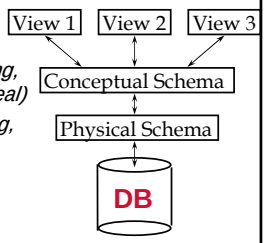
Why Study the Relational Model?

- **Most widely used model currently.**
  - DB2, MySQL, Oracle, PostgreSQL, SQLServer, ...
  - Note: some "Legacy systems" use older models
    - e.g., IBM's IMS
- **Object-oriented concepts have recently merged in**
  - *object-relational model*
    - Informix, IBM DB2, Oracle 8i
    - Early work done in POSTGRES research project at Berkeley
- XML (semi-structured)models emerging?

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

Example: University Database



- **Conceptual schema:**
  - *Students*(sid: *string*, name: *string*, login: *string*, age: *integer*, gpa:*real*)
  - *Courses*(cid: *string*, cname:*string*, credits:*integer*)
  - *Enrolled*(sid:*string*, cid:*string*, grade:*string*)
- **External Schema (View):**
  - *Course_info*(cid:*string*,enrollment:*integer*)
- **One possible Physical schema :**
  - Relations stored as unordered files.
  - Index on first column of Students.

Ex: An 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 must be unique (set semantics)

- Q: Do all values in each column of a relation instance have to be Unique?
- Q: Is "Cardinality" a schema property?
- Q: Is "Arity" a schema property?

SQL - A language for Relational DBs

- **SQL (a.k.a. "Sequel"),**
  - "Intergalactic Standard for Data"
  - Stands for Structured Query Language

  Two sub-languages:
- **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

FORIEGN Key

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

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 *candidate 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 candidate keys is chosen (by DBA) to be the ***primary key*.**

  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(
 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.

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 that we focus on in this class.
- **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

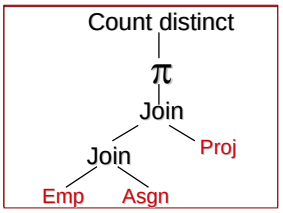
- **A *conceptual evaluation method* for the previous query:**
  1. do FROM clause: compute *cross-product* of Students and Enrolled
  2. do WHERE clause: Check conditions, discard tuples that fail
  3. do SELECT clause: Delete unwanted fields
- **Remember, this is *conceptual*. Actual evaluation will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

Queries, Query Plans, and Operators

```
SELECT
    COUNT DISTINCT (E.eid)
FROM Emp E, Proj P, Asgn A
WHERE E.eid = A.eid
    AND P.pid = A.pid
    AND E.loc <> P.loc
```



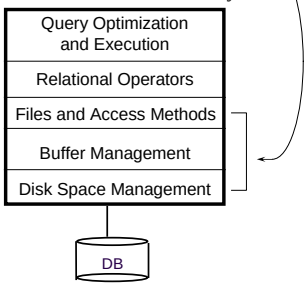
- **System handles query plan generation & optimization; ensures correct execution.**

- **Issues: view reconciliation, operator ordering, physical operator choice, memory management, access path (index) use, ...**

Structure of a DBMS

- **A typical DBMS has a layered architecture.**
- **The figure does not show the concurrency control and recovery components.**
- **Each system has its own variations.**
- **The book shows a somewhat more detailed version.**
- **You will see the "real deal" in PostgreSQL.**
  - It's a pretty full-featured example
- **Next class: we will start on this stack, bottom up.**

These layers must consider concurrency control and recovery



Relational Model: Summary

- A tabular representation of data.
- Simple and intuitive, currently the most widely used
  - Object-relational variant gaining ground
- 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

Administrivia IV - Don't Forget

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