CS 3DB3
RELATIONAL DATA MODEL

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Describing Data: Data Models

- A *data model* is a collection of concepts for describing data.
- A *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.
  - Use tables to represent data and relationships
  - Every relation has a *schema*, which describes the columns, or attributes.

Acknowledgement: Renee J. Miller

Relational Model

- Proposed by Edgar. F. Codd in 1970 as a data model which strongly supports data independence.
- Made available in commercial DBMSs in 1981 -- it is not easy to implement data independence efficiently and reliably!
- It is based on (a variant of) the mathematical notion of ***relation***.
- Relations are represented as tables.

A relation is a table

Relation Name

Students

Attribute Names

Tuples (Records)

ID	**Name**
2225555	Peter Jones
1234567	Amber Smith

The set of permitted values for an attribute is called the attribute ***domain***.
E.g., domain(ID) = {2225555, 1234567}.

Relational Data Model

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- *Relation schema* = relation name and attribute list.
  - Optionally: types of attributes. For example:
  - *Students(id, name)*
  - *Students(id: string, name: string)*
- *Relation* = set of tuples conforming to schema
  - Example:
    - {(2225555, Peter Jones), (1234567, Amber Smith), ...}
- *Database* = set of relations.
- *Database schema* = set of all relation schemas in the database.

Why Relations?

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- Very simple model.
- Often matches how we think about data.
- Abstract model that underlies SQL, the most important database language today.

Relations are Unordered

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- Order of tuples is irrelevant (tuples may be stored in an arbitrary order)
- E.g., *instructor* relation with unordered tuples

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
10101	Srinivasan	Comp. Sci.	65000
58583	Califieri	History	62000
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

Database

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- Information about an enterprise is broken up into parts

  instructor
  student
  advisor
- Bad design:
  univ (instructor_ID, name, dept_name, salary, student_Id, ..)
  results in
  - repetition of information (e.g., two students have the same instructor)
  - the need for NULL values (e.g., represent an student with no instructor)
- Normalization theory deals with how to design "good" relational schemas

Database Schemas in SQL

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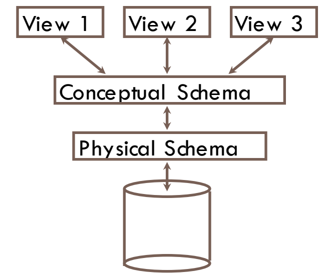
- SQL is primarily a query language, for getting information from a database.
- But SQL also includes a *data-definition* component for describing database schemas.

Levels of Abstraction

- Many *views*, single *conceptual (logical) schema* and *physical schema*.
  - Views describe how users see the data.
  - Conceptual schema defines logical structure
  - Physical schema describes the files and indexes used.



☛ *Schemas are defined using DDL (data definition language);*
☛ *Data is modified/queried using DML (data manipulation language).*

Example: University Database

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- 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)*
- Physical schema:
  - Relations stored as unordered files.
  - Index on first column of Students.
- External Schema (View):
  - *Course_info(cid:string,enrollment:integer)*

Integrity Constraints

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- An *integrity constraint* is a property that must be satisfied by all meaningful database instances.
- A constraint can be seen as *a predicate*; a database is *legal* if it satisfies all integrity constraints.
- Types of constraints
  - Intra-relational constraints: e.g., *domain constraints* and *tuple constraints*
  - Inter-relational constraints: most common is *referential constraint*

Tuple and Domain Constraints

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- A *tuple constraint* expresses conditions on the values of each tuple, independently of other tuples.
- E.g., **Net = Amount-Deductions**
- A *domain constraint* is a tuple constraint that involves a single attribute
- e.g., **(GPA ≤ 4.0) AND (GPA ≥ 0.0)**

Unique Values for Tuples

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RegNum	Surname	FirstName	BirthDate	DegreeProg
284328	Smith	Luigi	29/04/59	Computing
296328	Smith	John	29/04/59	Computing
587614	Smith	Lucy	01/05/61	Engineering
934856	Black	Lucy	01/05/61	Fine Art
965536	Black	Lucy	05/03/58	Fine Art

- Registration number identifies students, i.e., there is no pair of tuples with the same value for **RegNum**.
- Personal data could identify students as well, i.e., there is no pair of tuples with the same values for all of **Surname**, **FirstName**, **BirthDate**.

Keys

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- A *key* is a set of attributes that uniquely identifies tuples in a relation.
- More precisely:
  - A set of attributes K is a *superkey* for a relation r if r cannot contain two distinct tuples t_1 and t_2 such that $t_1[K]=t_2[K]$;
  - K is a *(candidate) key* for r if K is a minimal superkey

(that is, there exists no other superkey K' of r that is contained in K as proper subset, i.e, $K' \subset K$)

Example

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RegNum	Surname	FirstName	BirthDate	DegreeProg
284328	Smith	Luigi	29/04/59	Computing
296328	Smith	John	29/04/59	Computing
587614	Smith	Lucy	01/05/61	Engineering
934856	Black	Lucy	01/05/61	Fine Art
965536	Black	Lucy	05/03/58	Fine Art

- **RegNum** is a key: i.e., **RegNum** is a superkey and it contains a sole attribute, so it is minimal.
- **{Surname, Firstname, BirthDate}** is another key

Beware!

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RegNum	Surname	FirstName	BirthDate	DegreeProg
296328	Smith	John	29/04/59	Computing
587614	Smith	Lucy	01/05/61	Engineering
934856	Black	Lucy	01/05/61	Fine Art
965536	Black	Lucy	05/03/58	Engineering

- There is no pair of tuples with the same values on both `Surname` and `DegreeProg`;

  i.e., in each program students have different surnames; can we conclude that `Surname` and `DegreeProg` form a key for this relation?

  No! There ***could be*** students with the same surname in the same program

Existence of Keys

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- Relations are sets; therefore each relation is composed of distinct tuples.
- It follows that the whole set of attributes for a relation defines a **superkey**.
- Therefore **each relation has a key**, which is the set of all its attributes, or a subset thereof.
- The existence of keys guarantees that each piece of data in the database can be accessed,
- Keys are a major feature of the Relational Model and allow us to say that it is "**value-based**".

Keys and Null Values

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If there are nulls, keys do not work that well:
- They do not guarantee unique identification;
- They do not help in establishing correspondences between data in different relations

RegNum	Surname	FirstName	BirthDate	DegreeProg
NULL	Smith	John	NULL	Computing
587614	Smith	Lucy	01/05/61	Engineering
934856	Black	Lucy	NULL	NULL
NULL	Black	Lucy	05/03/58	Engineering

- Are the third and fourth tuple the same?
- How do we access the first tuple?

Primary Keys

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- The presence of nulls in keys has to be limited.
- Each relation must have a *primary key* on which nulls are not allowed (in any attribute)
- Notation: the attributes of the primary key are *underlined*
- References between relations are realized through primary keys

RegNum	Surname	FirstName	BirthDate	DegreeProg
643976	Smith	John	NULL	Computing
587614	Smith	Lucy	01/05/61	Engineering
934856	Black	Lucy	NULL	NULL
735591	Black	Lucy	05/03/58	Engineering

Do we Always Have Primary Keys?

- In most cases, we do have reasonable primary keys (e.g., student number, SIN)
- There may be multiple keys, one of which is designated as primary.

Recap

- A set of fields is a *key* for a relation if:
  1. No two distinct tuples can have same values in all key fields, and
  2. This is not true for any subset of the key.
- If #2 false, then a *superkey*.
- If there's >1 key for a relation, one of the keys is chosen to be the *primary key*.
- E.g., *sid* is a key for Students. (What about *name*?) The set {*sid, gpa*} is a superkey.