Relational Model 1: Tables and Keys

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The relational model is the *de facto* standard implemented in all the major database systems. It defines:

1. the format by which data should be stored;
2. the operations for querying the data.

We will focus on the first aspect in this lecture, leaving the second aspect to the next lecture.

A database conforming to the relational model is called a relational database.

Table, a.k.a. Relation

In a relational database, data are stored in tables.

PROF

pid	name	dept	rank	sal
$p1$	Adam	CS	asst	6000
$p2$	Bob	EE	asso	8000
$p3$	Calvin	CS	full	10000
$p4$	Dorothy	EE	asst	5000
$p5$	Emily	EE	asso	8500
$p6$	Frank	CS	full	9000
		...		

- Each row is also called a tuple.
- Each column is also called an attribute.
- The relation schema of a table is the set of its attribute names.
  - E.g., the schema of the above table is {pid, name, dept, rank, sal}.

Schema Examples

PROF

pid	**name**	**dept**	**rank**	**sal**
$p1$	Adam	CS	asst	6000
$p2$	Bob	EE	asso	8000
$p3$	Calvin	CS	full	10000
$p4$	Dorothy	EE	asst	5000
$p5$	Emily	EE	asso	8500
$p6$	Frank	CS	full	9000

CLASS

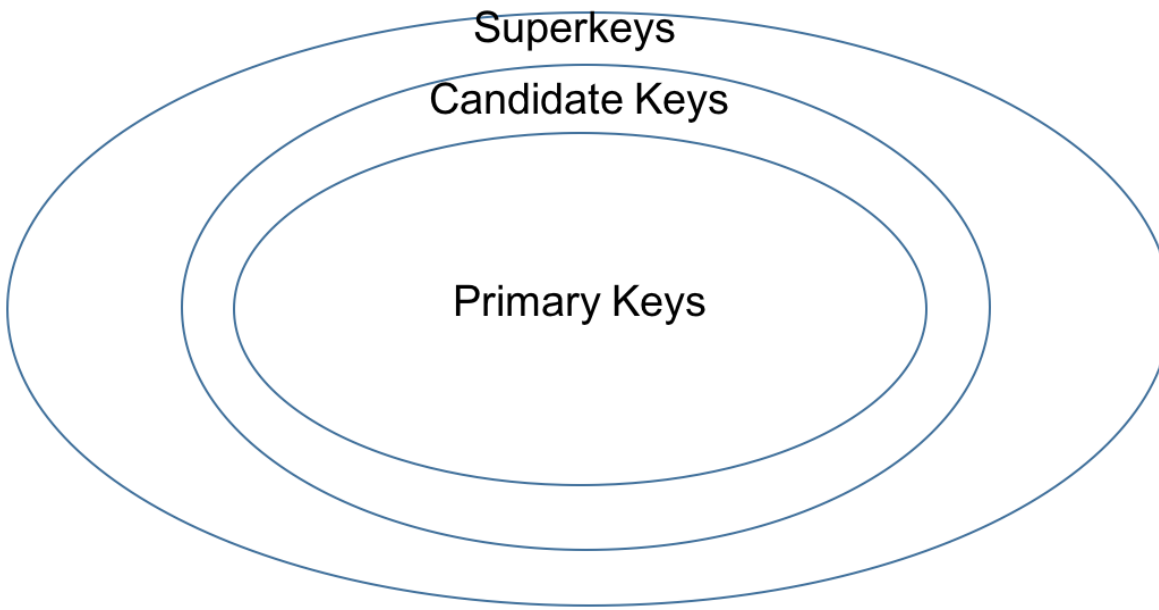
cid	**title**	**dept**	**year**
$c1$	database	CS	2011
$c2$	signal processing	EE	2012
$c1$	database	CS	2012

- optionally, attributes have domains; like types in a programming language

- A relation is a set of tuples, which means:
  - there can be no duplicate tuples (but in practise, commercial DBMSs allow duplicate rows)
  - order of the tuples doesn't matter
  - order of the attributes doesn't matter

- key: a set of attributes for which no two rows can have the same values

- Superkey
- Candidate key
- Primary key
- Foreign key



Superkey

Definition

Superkey: a set of one or more attributes whose combined values are unique. I.e., no two tuples can have the same values on these attributes.

- There may be more than one superkey.
- "Superkey" because it is a superset of some key.

Example

- In the PROF table (pid, name, dept, rank, sal) in Slide 3, {pid} is a key. Hence, all the following are super keys:
- {pid}, {pid, name}, {pid, dept}, {pid, rank, sal}, $\cdots$

Example

PROF

pid	name	dept	rank	sal
*p*1	Adam	CS	asst	6000
*p*2	Bob	EE	asso	8000
*p*3	Calvin	CS	full	10000
*p*4	Dorothy	EE	asst	5000
*p*5	Emily	EE	asso	8500
*p*6	Frank	CS	full	9000

Consider these superkeys and a new tuple to add to PROF

{pid} - p1, Adam, CS, asso, 7000 (conflict with p1)
{name, dept} - p6, Dorothy, EE, asst, 7000 (conflict with p4)
{pid, sal} - p5, Emily, EE, asst, 8500 (conflict with p5)
{pid, sal} - p1, Markus, EE, asst, 8500 (OKAY!)

Candidate Key

Definition

In a table, a candidate key is a minimal set K of attributes such that no two tuples are allowed to be equivalent on all the attributes in K.

E.g., in the PROF table of the previous slide, if we set {pid} as a candidate key, then no two tuples can have the same pid.

- A candidate key is designated when the table is created.
- There can be multiple candidate keys.
  - E.g., if you want, you can specify {name} as another candidate key, but do you think it makes sense?
  - How about {dept, rank}?

Discussion

CLASS

cid	**title**	**dept**	**year**
$c1$	database	CS	2011
$c2$	signal processing	EE	2012
	...		

How would you set a candidate key?

- {cid}?
- {dept}?
- {title}?
- {year}?
- {title, year}?
- {cid, dept}?
- {cid, year}?

CLASS

cid	**title**	**dept**	**year**
*c*1	database	CS	2011
*c*2	signal processing	EE	2012
	...		

Note

A university stores the whole history of its modules in the CLASS database/table.

Example cid(s): CS-250, EE-301, MA-101

Be careful about the assumptions?

- {cid}: in the history of the university, each course (same cid) can only be offered once
- {dept}: in the history of the university, each department can have one course. If you want to add one more course, need a different department.
- {title}: in the history of the university, each course title can be used once.
- {cid, dept}: over the history of the university, each course of each dept can only be offered once.
- {title, year}: each course with different title can be offered once per year. Problem: Project Management at CS and EE, offered in year 2012.
- {cid, year}: each course with different course code can be offered once per year. Best option.
- Problem: how about offer twice, fall and spring semester?

Why important?

Can I set the candidate key { cid, dept, year } ?

Class			
cid	**title**	**dept**	**year**
CS250	database	CS	2011
EE101	signal processing	EE	2012
	...		

Why important?

Can I set the candidate key { cid, dept, year } ?

Class			
cid	**title**	**dept**	**year**
CS250	database	CS	2011
EE101	signal processing	EE	2012
CS300	Project Management	CS	2013
CS300	Project Management	EE	2013

Consider these? What do you see?

Class			
cid	**title**	**dept**	**year**
CS250	database	CS	2011
EE101	signal processing	EE	2012
CS300	Project Management	CS	2013
CS300	Project Management	EE	2013

- In general, the cid relates to a dept.
- { cid, dept, year } is not useful – It allow mistakes to occur!

Class			
cid	**title**	**dept**	**year**
CS250	database	CS	2011
EE101	signal processing	EE	2012
CS300	Project Management	CS	2013
CS300	Project Management	EE	2013

- In general, the cid relates to a dept.
- { cid, dept, year } is not useful – It allow mistakes to occur!

- {cid, year} - candidate key (minimal)

Class			
cid	**title**	**dept**	**year**
CS250	database	CS	2011
EE101	signal processing	EE	2012
CS300	Project Management	CS	2013
CS300	Project Management	EE	2013

- In general, the cid relates to a dept.
- { cid, dept, year } is not useful – It allow mistakes to occur!

- {cid, year} - candidate key (minimal)
- {cid, dept, year} - superkey

As a good practice, every table should have at least a candidate key, a convention that will be enforced in the rest of the course. This implies that no two tuples in the table can be entirely equivalent to each other (think: why?).

well... to remove redundancy.

Choosing a key

- Need to know not just that there are no duplicates now, but that there in principle cannot be any.
- Is every relation guaranteed to have a key?
- Often we have to invent an artificial new attribute to ensure all tuples will be unique. Eg, NI number, ISBN number.
- A key is a kind of integrity constraint.

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- Is every relation guaranteed to have a key?
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- A key is a kind of integrity constraint.

Primary Key

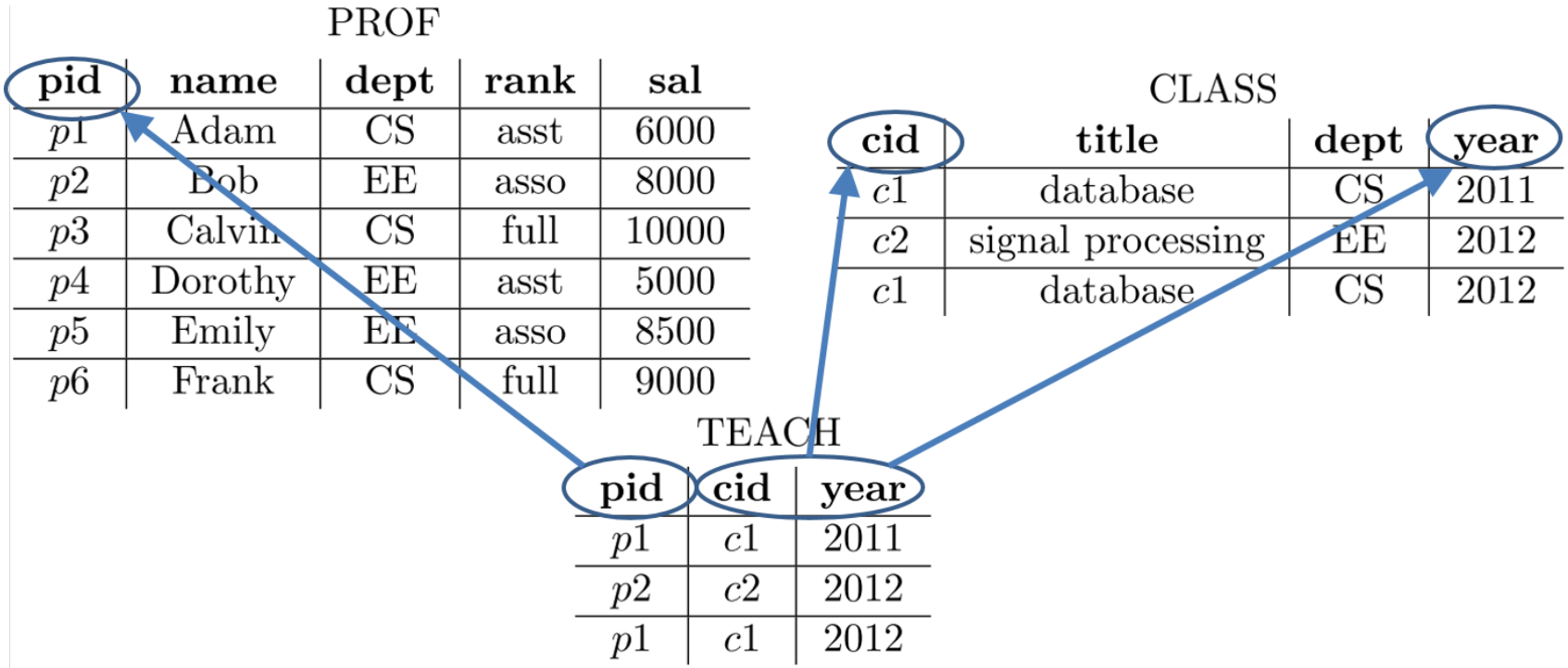
Primary key - one of the candidate keys chosen by DB designer.

Foreign Key

Definition

Let T and T' be two tables, and K a candidate key in T. If T' also contains K, then K is a foreign key of T' referencing T.

See the next slide for an example.



Suppose that PROF has a candidate key pid, and CLASS has a candidate key cid, year. Then

- {pid}: is a foreign key of TEACH referencing PROF.
- {cid, year}: is a foreign key of TEACH referencing CLASS.

PROF

pid	name	dept	rank	sal
$p1$	Adam	CS	asst	6000
$p2$	Bob	EE	asso	8000
$p3$	Calvin	CS	full	10000
$p4$	Dorothy	EE	asst	5000
$p5$	Emily	EE	asso	8500
$p6$	Frank	CS	full	9000

CLASS

cid	title	dept	year
$c1$	database	CS	2011
$c2$	signal processing	EE	2012
$c1$	database	CS	2012

TEACH

pid	cid	year
$p1$	$c1$	2011
$p2$	$c2$	2012
$p1$	$c1$	2012

These violate referential constraint (foreign key) in TEACH:

<p10, c1, 2012> - p10 does not exist in PROF

<p2, c3, 2016> - c3, 2016 does not exist in CLASS

Discussion

PROF

pid	**name**	**dept**	**rank**	**sal**
$p1$	Adam	CS	asst	6000
$p2$	Bob	EE	asso	8000
$p3$	Calvin	CS	full	10000
$p4$	Dorothy	EE	asst	5000
$p5$	Emily	EE	asso	8500
$p6$	Frank	CS	full	9000
		...		

CLASS

cid	**title**	**dept**	**year**
$c1$	database	CS	2011
$c2$	signal processing	EE	2012
$c1$	database	CS	2012
	...		

TEACH

pid	**cid**	**year**
$p1$	$c1$	2011
$p2$	$c2$	2012
$p1$	$c1$	2012
	...	

How would you designate a candidate key for TEACH?

- {pid}: professor can only teach one class throughout history.
- {cid, year}: it allows professor to teach multiple classes. Most importantly, each class of a particular year can only be taught by one professor.
- {pid, cid, year}: professor may teach many classes. class may be taught by multiple professors.

Roadmap - next couple of lectures

- We will learn how to define a database's structure and write queries on it.
- We will learn these first in the relational model, then in SQL because:
  - the relational model and algebra are the foundation for SQL
  - other important concepts, like query optimization, are defined in terms of relational algebra

Important

FAQ

So far, we seem to pick the keys in a very ad-hoc way (by guessing/try-and-error). We will cover more theories (esp. functional dependencies in week7). After that, we will formally introduce "HOW" to define candidate keys properly. Stay tuned.

For today, make sure you understand:

- Definitions of: superkeys, candidate keys, primary keys, foreign keys
- The meaning of keys
- The use of keys