Relational Model

CS 6070 Databases

Kennesaw State University

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Relational Data Model

A *relation schema* $R(A_1, ..., A_n)$ is a relation name R and a list of attributes $A_1, ..., A_n$.

Each attribute A_i is the name of a role played by some domain D.

- Example: $AUTHOR(author\_id, first\_name, last\_name)$
  - $dom(A_1)$ (or $dom(author\_id)$) is integer
  - The role played by an integer in A_1 is that of an identifier/key.

A *database schema* is a collection of relation schemas.

- Example: *PUBS* database has relation schemas *BOOK*, *AUTHOR*, and *PUB* (for publication, not public house)

Relations and Databases

A *relation*, or *relation state*, $r(R)$ is a **set** of tuples that conform to a *relation schema* R.

- Example: given $AUTHOR(author\_id, first\_name, last\_name)$, a particular $r(AUTHOR) =$

author_id	first_name	last_name
1	John	McCarthy
4	Claude	Shannon
5	Alan	Turing
6	Alonzo	Church

A *database* is a set of relations.

Tuples

A *tuple* is an **ordered list** of values.

- Example: $t_1 = <1$, 'John', 'McCarthy'$>$

Each value in the tuple is that tuple's value for the corresponding attribute of the relation schema.

Example: (these are equivalent notations):

- $t_1[\mathit{first\_name}] =$ 'John' (bracket notation)
- $t_1.\mathit{first\_name} =$ 'John' (object notation)
- $t_1[2] =$ `'John'` (positional notation)

The *degree* or *arity* of a relation schema is the number of attributes it has.

- Example: *AUTHOR* has degree 3.

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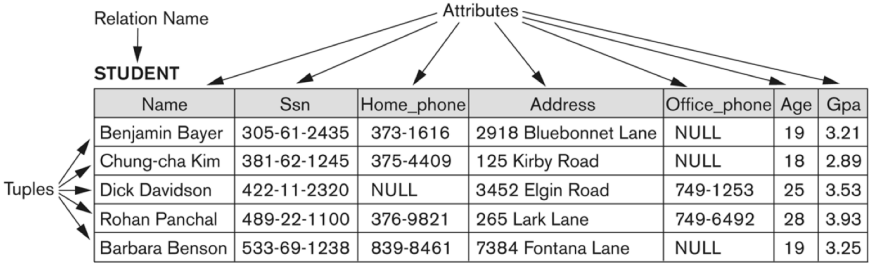
Attributes and Domains

Each attribute has a name and a *domain*

- The name describes the role played by the attribute
  - Example: the *first_name* attribute of the *AUTHOR* schema plays the role of the first name of an author represented by a tuple in a $r(AUTHOR)$ relation.
- The domain is a set of atomic values that a tuple may have for that attribute.
- A domain has a *logical definition*, e.g., integer or string, and may also have a *format*.
  - Example: `Home_phone` as $ddd - dddd$, where d is a digit



Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Benjamin Bayer	305-61-2435	373-1616	2918 Bluebonnet Lane	NULL	19	3.21
Chung-cha Kim	381-62-1245	375-4409	125 Kirby Road	NULL	18	2.89
Dick Davidson	422-11-2320	NULL	3452 Elgin Road	749-1253	25	3.53
Rohan Panchal	489-22-1100	376-9821	265 Lark Lane	749-6492	28	3.93
Barbara Benson	533-69-1238	839-8461	7384 Fontana Lane	NULL	19	3.25

Figure 5.1
The attributes and tuples of a relation STUDENT.

Mathematical Definition of Relation

Given $R(A_1, ..., A_n)$,

- $r(R) \subseteq (dom(A_1) \times dom(A_2) \times ... \times dom(A_n))$

The total number of values, or *cardinality*, of a domain D is $|D|$.

So the maximum number of tuples that could possibly be in $r(R)$ is

- $|dom(A_1)| * |dom(A_2)| * ... * |dom(A_n)|$

Example: given

- $R(A_1, A_2)$
- $dom(A_1) = \{1, 2\}$, $dom(A_2) = \{a, b\}$

What are all the possible tuples that could appear in any $r(R)$?

Enumerating Tuples

Example: given

- $R(A_1, A_2)$
- $dom(A_1) = \{1, 2\}$, $dom(A_2) = \{a, b\}$

What are all the possible tuples that could appear in any $r(R)$?

$$dom(A_1) \times dom(A_2) = \{< 1, a >, < 1, b >, < 2, a >, < 2, b >\}$$

Given the definition of a *relation* or *relation state*, what is the maximum size of any $r(R)$?

Properties of Relations

- Atomicity of values, i.e., the First Normal Form assumption
  - Attribute values in tuples are indivisible, e.g., no compound or multivalued attributes as in EER models
- Nulls may appear in tuples for *some* attributes (more later)
  - Unknown, not applicable, not existing
- Closed world assumption
  - Facts not asserted explicitly are assumed to be false

Consider the properties above in the context of the following relation.

author_id	first_name	middle_name	last_name
1	John	NULL	McCarthy
4	Claude	Elwood	Shannon
5	Alan	Mathison	Turing
6	Alonzo	NULL	Church

Superkeys

A *superkey SK* is a set of attributes of a relation schema R such that

$$t_i[SK] \neq t_j[SK]$$

for any $i \neq j$.

In other words, the values of the superkey attributes of a tuple uniquely identify the tuple within the relation.

By the definition of the relational model, the full attribute set of a relation schema is a *default superkey*.

- Pause for a moment and make sure you understand that last statement.

Keys

A *minimal superkey* is a superkey for which removing an attribute would make it no longer a superkey.

We call a minimal superkey a *key*.

A relation schema may have several keys. We call these *candidate keys* and choose one arbitrarily to be the *primary key*.

We underline the primary key in a relation schema.

- Example: $AUTHOR(\underline{author\_id}, first\_name, last\_name)$

Database Integrity Constraints

- Inherent model-based (or *implicit*) constraints
  - Domain constraints: attribute values in tuples must be in domain for that attribute and conform to formats
  - Atomic attribute values
- Schema-based (or *explicit*) contstraints
  - Key constraints: no two tuples can have the same values for the primary key
  - Entity Integrity Constraints: no tuple can have a NULL value for its primary key attribute
  - Referential Integrity Constraints: tuples in one relation referencing tuples in another relation
- Application-based (or semantic constraints), a.k.a., business rules
  - Constraints on attribute values that cannot be expressed in the relational model

Referential Integrity Constraints

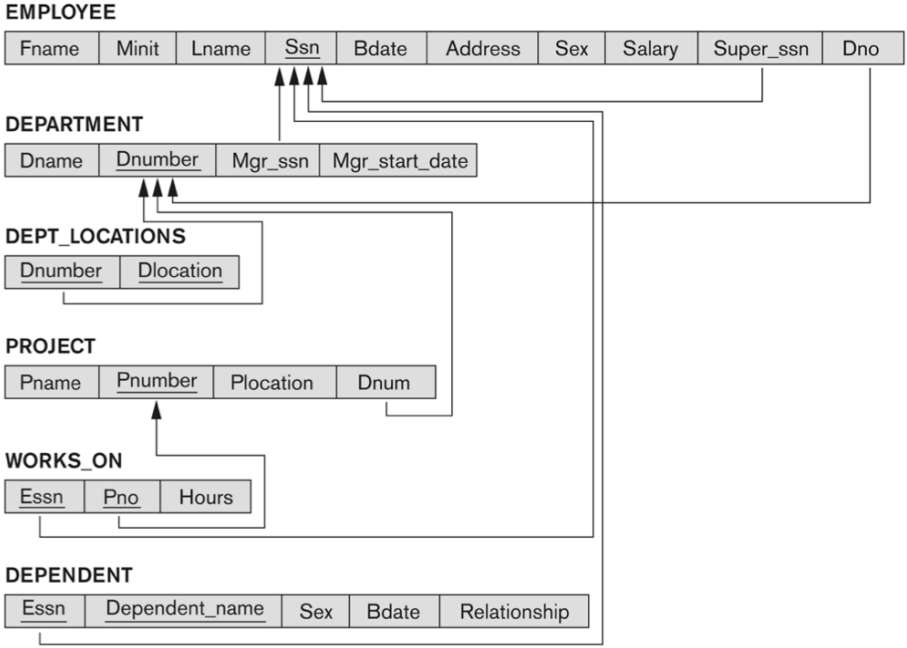
A foreign key value from a tuple in one relation must refer to nothing, or to the primary key for an existing tuple in another relation. Formally:

Given relation schemas R_1 and R_2, a set of attributes FK in R_1 is a foreign key referencing R_2 if

- the attributes in FK in R_1 have same domains as PK in R_2, and
- given some t_1 in $r_1(R_1)$ and t_2 in $r_2(R_2)$, either $t_1[FK] = t_2[PK]$ or $t_1[FK]$ is NULL.

R_1 is the referencing, or child relation, R_2 is the referenced, or parent relation.

Diagramming FK Relationships



Semantic Integrity Constraints

- Can't be specified in DDL
- Can be checked with triggers and assertions
- Usually checked in application code

Example: salary of an employee cannot exceed the salary of the employee's supervisor.

Constraint Violations on Insert, Update or Delete

- Domain constraints
  - Insert/update a tuple with an attribute value not in attribute's domain
- Key constraints
  - Insert/update a tuple with a key that's already in the relation state
- Entity integrity constraints
  - Insert/update a tuple with a NULL value for any part of the primary key
- Referential integrity constraints
  - Insert/update a tuple in a referring relation whose FK does not appear as a PK value in any tuple of the referenced relation
  - Update the primary key for a tuple in a referenced relation for which there are tuples in referring relationships. The tuples in referring relationships would be orphaned or end up referring to the wrong parent tuple.
  - Delete a tuple in a referenced relation for which there are tuples in referring relations. The tuples in referring relations would be orphaned.

Domain Integrity Violation Examples

author_id	first_name	last_name
1	John	McCarthy
4	Claude	Shannon
5	Alan	Turing
6	Alonzo	Church

$dom(author\_id) = \text{integer}$, $dom(first\_name) = \text{string}$, $dom(last\_name) = \text{string}$

- Insert `<"Two", "Jenny", "McCarthy">` – `"Two"` is not in $dom(author\_id)$
- Update `<1, "John", "McCarthy">` to `<1, "John", 1>` – `1` is not in $dom(last\_name)$

Key Integrity Violation Examples

author_id	first_name	last_name
1	John	McCarthy
4	Claude	Shannon
5	Alan	Turing
6	Alonzo	Church

- Insert `<1, "Jenny", "McCarthy">` – `1` is an existing primary key
- Update `<1, "John", "McCarthy">` to `<6, "John", "McCarthy">` – `6` is an existing primary key

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Entity Integrity Violation Examples

author_id	first_name	last_name
1	John	McCarthy
4	Claude	Shannon
5	Alan	Turing
6	Alonzo	Church

- Insert <NULL, "Jenny", "McCarthy"> – NULL not allowed for primary key
- Update <NULL, "John", "McCarthy"> to <1, "John", 1>– NULL not allowed for primary key

Referential Integrity Violation Examples

author

id	first_name	last_name
1	John	McCarthy
4	Claude	Shannon
5	Alan	Turing
6	Alonzo	Church

pub

id	title	author_id
1	Recursive Functions of Symbolic ...	1
2	A Mathematical Theory of Communication	4
4	Computing machinery and intelligence	5
5	The calculi of lambda-conversion	6

`pub[author_id]` is a foreign key to the `author` relation.

- Update `<1, "John", "McCarthy">` to `<2, "John", "McCarthy">` – breaks reference from `pub[id] = 1`.
- Delete `<5 "Alan", "Turning">` from `author` – orhpans tuple from `pub`.
- Update `<5, "The calculi of lambda-conversion", 6>` – `<5, "The calculi of lambda-conversion", 7>` – 7 is not a primary key in `pub`.
- Update `<5, "The calculi of lambda-conversion", 6>` – `<5, "The calculi of lambda-conversion", NULL>` – strictly speaking, not a violation, but creates bad data. We'll see how to prevent that when we learn SQL.

Closing Thoughts

- The relational model is a mathematical database model.
- Aside from its rigorous grounding, a strength of the relational model is its modeling (and, in DBMS systems, enforcement) of constraints.
- Relational data model is especially valuable if the integrity of your data is important.