Relational Data Model

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Relational Data Model

A relation schema $R(A_a, ..., A_n)$ 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

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: $r(AUTHOR) =$

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 that is part of a relation

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

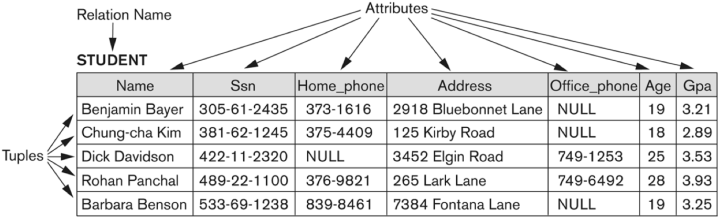
Each value in the tuple is that tuple's value for the corresponding attribute of the relation schema.
Example: (these are equivalent notations):

- $t_1[first\_name]$ = 'John' (bracket notation)
- $t_1.first\_name$ = '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.

An Example Relation


Relation Name
Attributes
Tuples

STUDENT

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.

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 logical definition of a domain specifies a simple type such as integer or string, and a data type or format
  - Example: `USA_phone_number` as $(ddd)ddd - dddd$, where d is a digit

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

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

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
  - Unknown, not applicable, not existing
- Closed world assumption
  - Facts not asserted explicitly are assumed to be false

Kinds of Constraints

- Inherent model-based (or implicit) constraints
  - domain constraints, atomic attribute values
- Schema-based (or explicit) contstraints
  - keys, referential integrity
- Application-based (or semantic constraints), a.k.a., business rules

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.

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

- Domain constraints - Attribute values in tuples must be in domain for that attribute
- 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
- Semantic Integrity Constraints - Constraints on values of attributes that cannot be specified in the databases DDL

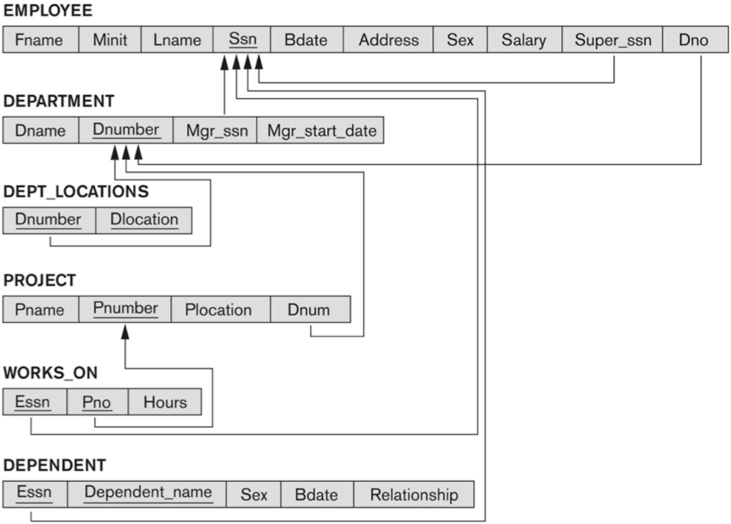
Referential Integrity Constraints

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
- 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 relation, R_2 is the referenced relation.

Diagramming FK Relationships



EMPLOYEE

Fname Minit Lname Ssn Bdate Address Sex Salary Super_ssn Dno

DEPARTMENT

Dname Dnumber Mgr_ssn Mgr_start_date

DEPT_LOCATIONS

Dnumber Dlocation

PROJECT

Pname Pnumber Plocation Dnum

WORKS_ON

Essn Pno Hours

DEPENDENT

Essn Dependent_name Sex Bdate Relationship

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

- Domain constraints
  - Insert a tuple with an attribute value not in attribute's domain
- Key constraints
  - Insert a tuple with a key that's already in the relation state
- Entity integrity constraints
  - Insert a tuple with a NULL value for any part of the primary key
- Referential integrity constraints
  - Insert a tuple in a referring relation whose FK does not appear as a PK value in any tuple of the referenced relation

Constraint Violations on Update

- Domain constraints
  - Update a tuple with an attribute value not in attribute's domain
- Key constraints
  - Update a tuple with a key value that already appears in another tuple in the relation
- Entity integrity constraints
  - Update a tuple with a NULL value for any part of the primary key
- Referential integrity constraints
  - Update a tuple in a refferring relation with a 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

Constraint Violations on Delete

- Referential integrity
  - Delete a tuple in a referenced relationship for which there are tuples in referring relationships. The tuples in referring relationships 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

$dom(author_id) = integer, dom(first_name) = string, dom(last_name) = string$

- 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

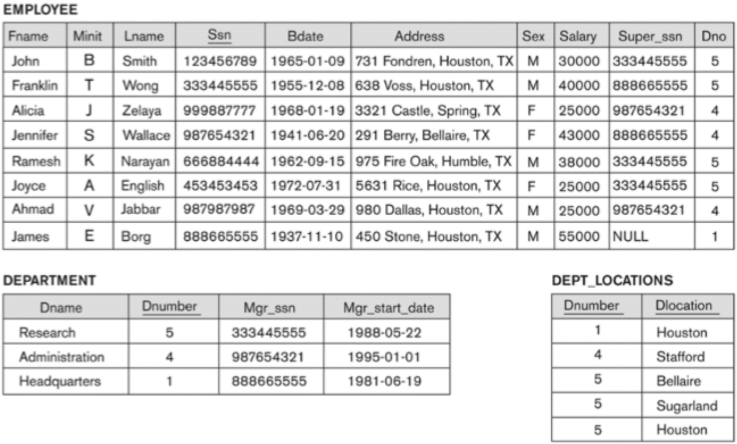
- Insert $< 1, ''Jenny'', ''McCarthy'' > -$ 1 is an existing primary key
- Update $< 6, ''John'', ''McCarthy'' >$ to $< 1, ''John'', 1 > -$ 6 is an existing primary key

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 Violations – Employee - Department Example



EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston