204222 - Fundamentals of Database Systems

Chapter 3

The Relational Data Model and Relational Database Constraints

Adapted for 204222

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Chapter 3 Outline

- The Relational Data Model and Relational Database Constraints
- Relational Model Constraints and Relational Database Schemas
- Update Operations, Transactions, and Dealing with Constraint Violations

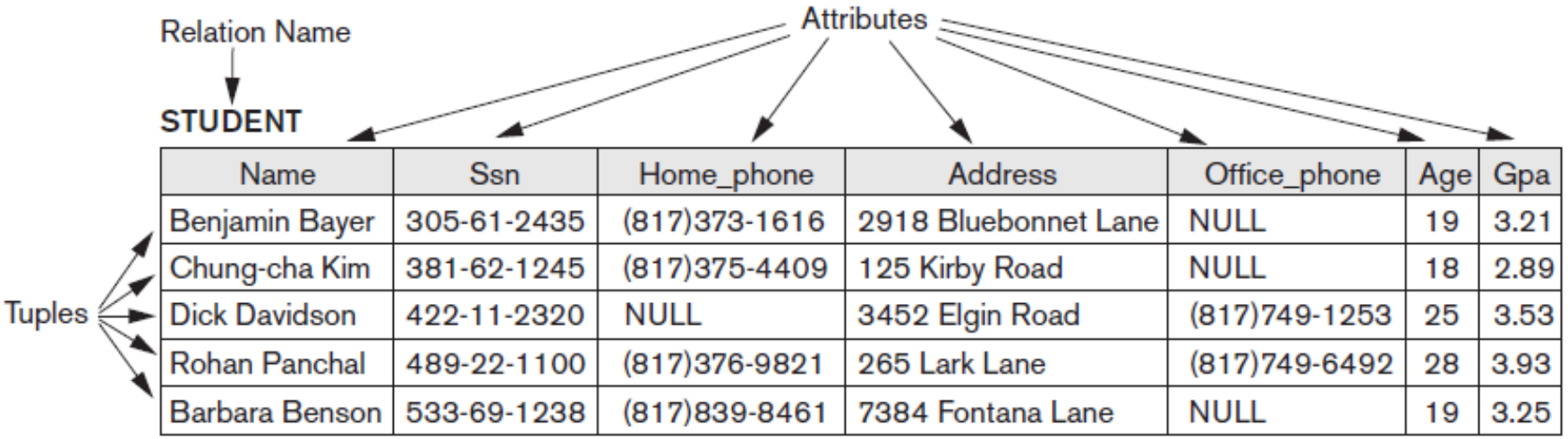
The Relational Data Model and Relational Database Constraints

- Relational model
  - First commercial implementations available in early 1980s
  - Has been implemented in a large number of commercial system
- Hierarchical and network models
  - Preceded (มาก่อน) the relational model

Relational Model Concepts

- Represents data as a collection of relations
- **Table** of values
  - Row
    - Represents a collection of related data values
    - Fact that typically corresponds to a real-world entity or relationship
    - ***Tuple***
  - Table name and column names
    - Interpret the meaning of the values in each row
      attribute

Relational Model Concepts (cont'd.)



Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Benjamin Bayer	305-61-2435	(817)373-1616	2918 Bluebonnet Lane	NULL	19	3.21
Chung-cha Kim	381-62-1245	(817)375-4409	125 Kirby Road	NULL	18	2.89
Dick Davidson	422-11-2320	NULL	3452 Elgin Road	(817)749-1253	25	3.53
Rohan Panchal	489-22-1100	(817)376-9821	265 Lark Lane	(817)749-6492	28	3.93
Barbara Benson	533-69-1238	(817)839-8461	7384 Fontana Lane	NULL	19	3.25

Figure 3.1
The attributes and tuples of a relation STUDENT.

Domains, Attributes, Tuples, and Relations

- **Domain** D
  - Set of atomic (indivisible) values
- **Atomic**
  - Each value indivisible (แบ่งแยกไม่ได้)
- Specifying a domain
  - **Data type** specified for each domain: แต่ละ domain ต้องมีการกำหนดลักษณะของข้อมูล

Domains, Attributes, Tuples, and Relations (cont'd.)

- **Relation schema** *R*
  - Denoted by $R(A_1, A_2, ..., A_n)$
  - Made up of a relation name *R* and a list of attributes, $A_1, A_2, ..., A_n$
  - Relation schema ประกอบด้วย ชื่อ relation *R* และ attributes $A_1, A_2, ..., A_n$ ของ *R*
  - แต่ละ Relation อยู่ในรูป $R(A_1, A_2, ..., A_n)$
- Attribute A_i
  - Name of a role played by some domain *D* in the relation schema *R*
- **Degree** (or **arity**) of a relation
  - Number of attributes n of its relation schema

Domains, Attributes, Tuples, and Relations (cont'd.)

- **Relation** (or **relation state**): Relation State คือสถานะของข้อมูลใน Relation ณ เวลาใดเวลาหนึ่ง ซึ่งแทนด้วย set ของ tuple (หรือ record) อยู่ในรูปแบบ $r = \{t_1, t_2, ..., t_m\}$
  - Set of ***n*-tuples** $r = \{t_1, t_2, ..., t_m\}$
  - Each n-tuple t
    - Ordered list of n values $t = <v_1, v_2, ..., v_n>$
    - Each value v_i, $1 \leq i \leq n$, is an element of dom(A_i) or is a special NULL value

Domains, Attributes, Tuples, and Relations (cont'd.)

- **Current relation state**
  - Relation state at a given time
  - Reflects only the valid tuples that represent a particular state of the real world
- Attribute names
  - Indicate different **roles**, or interpretations, for the domain

Characteristics of Relations (cont'd.)

Figure 3.2
The relation STUDENT from Figure 3.1 with a different order of tuples.

STUDENT

Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
Dick Davidson	422-11-2320	NULL	3452 Elgin Road	(817)749-1253	25	3.53
Barbara Benson	533-69-1238	(817)839-8461	7384 Fontana Lane	NULL	19	3.25
Rohan Panchal	489-22-1100	(817)376-9821	265 Lark Lane	(817)749-6492	28	3.93
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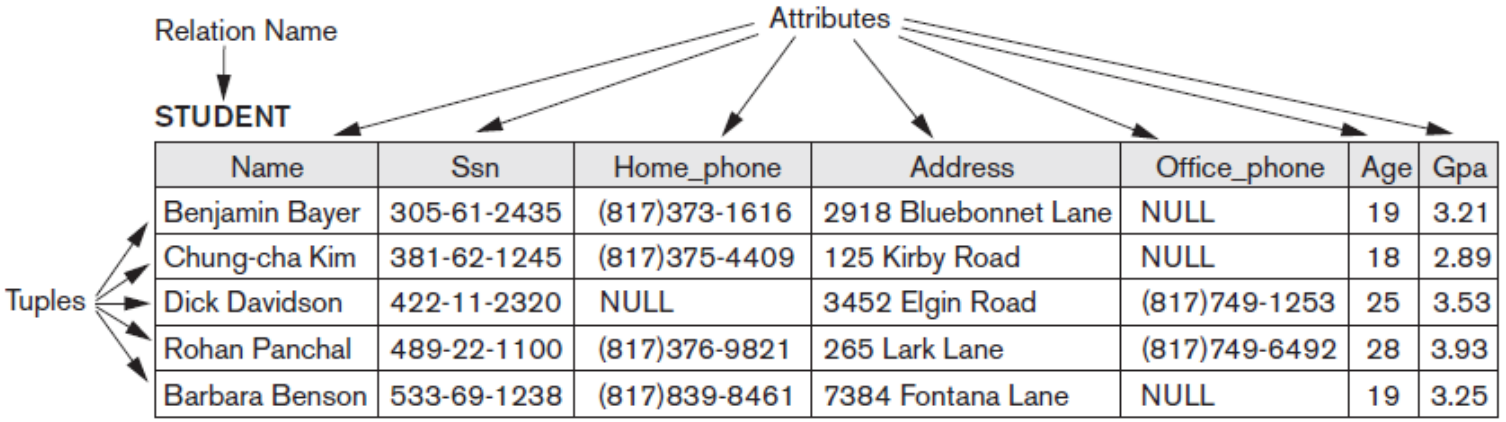

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Figure 3.1
The attributes and tuples of a relation STUDENT.

Characteristics of Relations (cont'd.)

- Values and NULLs in tuples
  - Each value in a tuple is atomic
  - **Flat relational model**
    - Composite and multivalued attributes not allowed
    - **First normal form** assumption
  - Multivalued attributes
    - Must be represented by separate relations
  - Composite attributes
    - Represented only by simple component attributes in basic relational model

Characteristics of Relations (cont'd.)

- NULL values
  - Represent the values of attributes that may be unknown or may not apply to a tuple
  - Meanings for NULL values
    - *Value unknown*
    - *Value exists but is not available* (บอกไม่ได้)
    - *Attribute does not apply to this tuple (also known as value undefined) ไม่ได้กำหนด*

Characteristics of Relations (cont'd.)

- Interpretation (meaning) of a relation
  - **Assertion**
    - Each tuple in the relation is a **fact** or a particular instance of the assertion
  - **Predicate**
    - Values in each tuple interpreted as values that satisfy predicate (state)

Relational Model Notation

- Relation schema *R* of degree *n (n attributes)*
  - Denoted by $R(A_1, A_2, ..., A_n)$
- Uppercase letters *Q*, *R*, *S*
  - Denote relation names
- Lowercase letters *q*, *r*, *s*
  - Denote relation states (เช่น $r = \{t_1, t_2, ..., t_m\}$)
- Letters *t*, *u*, *v*
  - Denote tuples (หรือ record หรือ row)

Relational Model Notation

- Name of a relation schema: STUDENT
  - Indicates the current set of tuples in that relation
- Notation: STUDENT(Name, Ssn, ...)
  - Refers only to relation schema
- Attribute *A* can be qualified with the relation name *R* to which it belongs
  - Using the dot notation *R.A (A คือ attribute ของ R)*

Relational Model Notation

- *n-tuple t* in a relation *r*(*R*)
  - Denoted by $t = \langle v_1, v_2, ..., v_n \rangle$
  - v_i is the value corresponding to attribute A_i
- Component values of tuples:
  - $t[A_i]$ and $t.A_i$ refer to the value v_i in t for attribute A_i :$t[A_i]$ and $t.A_i$ หมายถึง ค่าที่อยู่ใน attribute A_i ของ tuple t
  - $t[A_u, A_w, ..., A_z]$ and $t.(A_u, A_w, ..., A_z)$ refer to the subtuple of values $\langle v_u, v_w, ..., v_z \rangle$ from t corresponding to the attributes specified in the list

Relational Model Constraints

- Constraints
  - Restrictions on the actual values in a database state: กำหนดข้อบังคับของข้อมูลที่จะเข้าไปอยู่ในฐานข้อมูล
  - Derived from the rules in the miniworld that the database represents: ข้อบังคับได้มาจากความเป็นจริงของข้อมูล เช่น อายุของสิ่งมีชีวิตมีค่า > 0
- **Inherent model-based constraints** or **implicit constraints**
  - Inherent in the data model: ได้รับสืบทอดมาจากข้อบังคับของแต่ละ data model

Relational Model Constraints (cont'd.)

- **Schema-based constraints** or **explicit constraints**
  - Can be directly expressed in schemas of the data model: กฎข้อบังคับที่สามารถกำหนดโดยตรงใน data model หรือ database schema
- **Application-based** or **semantic constraints** or **business rules**
  - Cannot be directly expressed in schemas
  - Expressed and enforced by application program กฎข้อบังคับที่ไม่สามารถกำหนดโดยตรงใน data model หรือ database schema จะถูกกำหนดไว้ใน application program แทน เช่น ห้ามเบิก OT เกิน 4 ชั่วโมงในวันธรรมดา

Domain Constraints

- Typically include:
  - Numeric data types for integers and real numbers
  - Characters
  - Booleans
  - Fixed-length strings
  - Variable-length strings
  - Date, time, timestamp
  - Money
  - Other special data types

Key Constraints and Constraints on NULL Values

- No two tuples can have the same combination of values for all their attributes.
- **Superkey**
  - No two distinct tuples in any state *r* of *R* can have the same value for SK
- **Key**
  - Superkey of R
  - Removing any attribute *A* from *K* leaves a set of attributes *K* that is not a superkey of *R* any more

Key Constraints and Constraints on NULL Values (cont'd.)

- Key satisfies two properties:
  - Two distinct tuples in any state of relation cannot have identical values for (all) attributes in key
  - Minimal superkey
    - Cannot remove any attributes and still have uniqueness constraint in above condition hold

Key Constraints and Constraints on NULL Values (cont'd.)

- **Candidate key**
  - Relation schema may have more than one key
- **Primary key** of the relation
  - Designated among candidate keys
  - Underline attribute
- Other candidate keys are designated as **unique keys**

Key Constraints and Constraints on NULL Values (cont'd.)

CAR

License_number	Engine_serial_number	Make	Model	Year
Texas ABC-739	A69352	Ford	Mustang	02
Florida TVP-347	B43696	Oldsmobile	Cutlass	05
New York MPO-22	X83554	Oldsmobile	Delta	01
California 432-TFY	C43742	Mercedes	190-D	99
California RSK-629	Y82935	Toyota	Camry	04
Texas RSK-629	U028365	Jaguar	XJS	04

Figure 3.4
The CAR relation, with two candidate keys: License_number and Engine_serial_number.

Relational Databases and Relational Database Schemas

- **Relational database schema** *S*
  - Set of relation schemas $S = \{R_1, R_2, ..., R_m\}$
  - Set of integrity constraints IC
- **Relational database state**
  - Set of relation states $DB = \{r_1, r_2, ..., r_m\}$
  - Each r_i is a state of R_i and such that the r_i relation states satisfy integrity constraints specified in IC

Relational Databases and Relational Database Schemas (cont'd.)

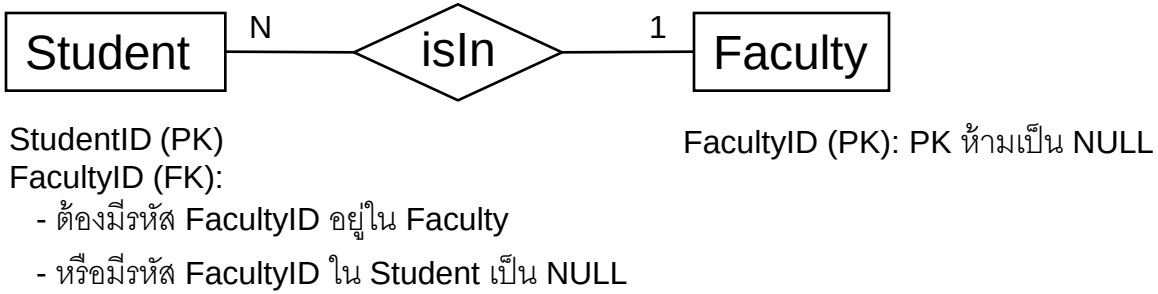
- **Invalid state**
  - Does not obey all the integrity constraints
- **Valid state**
  - Satisfies all the constraints in the defined set of integrity constraints IC

Integrity, Referential Integrity, and Foreign Keys

- **Entity integrity constraint**
  - No primary key value can be NULL
- **Referential integrity constraint**
  - Specified between two relations
  - Maintains consistency among tuples in two relations

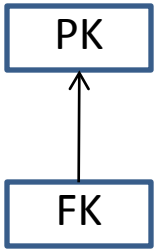
Integrity, Referential Integrity, and Foreign Keys (cont'd.)

- **Foreign key** rules:
  - The attributes in FK have the same domain(s) as the primary key attributes PK
  - Value of FK in a tuple t_1 of the current state $r_1(R_1)$ either occurs as a value of PK for some tuple t_2 in the current state $r_2(R_2)$ or is NULL



Integrity, Referential Integrity, and Foreign Keys (cont'd.)

- Diagrammatically display referential integrity constraints
  - Directed arc from each foreign key to the relation it references
- All integrity constraints should be specified on relational database schema



Other Types of Constraints

- Semantic integrity constraints
  - May have to be specified and enforced on a relational database
  - Use **triggers:** ผูกกับ **Insert Update Delete** and

    assertions: a statement that tests a database condition e.g. check to make sure that total loan never exceeds the total amount in the bank
  - More common to check for these types of constraints within the application programs

Other Types of Constraints (cont'd.)

- Functional dependency constraint
  - Establishes a functional relationship among two sets of attributes *X* and *Y*
  - Value of *X* determines a unique value of *Y*

  → จะได้เรียนใน FD และ Normalization
- **State constraints**
  - Define the constraints that a valid state of the database must satisfy
- **Transition constraints**
  - Define to deal with state changes in the database

Update Operations, Transactions, and Dealing with Constraint Violations

- Operations of the relational model can be categorized into retrievals and updates
- Basic operations that change the states of relations in the database:
  - Insert
  - Delete
  - Update (or Modify)

Figure 3.6
One possible database state for the COMPANY relational database schema.

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

Figure 3.6
One possible database state for the COMPANY relational database schema.

WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	NULL

PROJECT

Pname	Pnumber	Plocation	Dnum
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
333445555	Theodore	M	1983-10-25	Son
333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

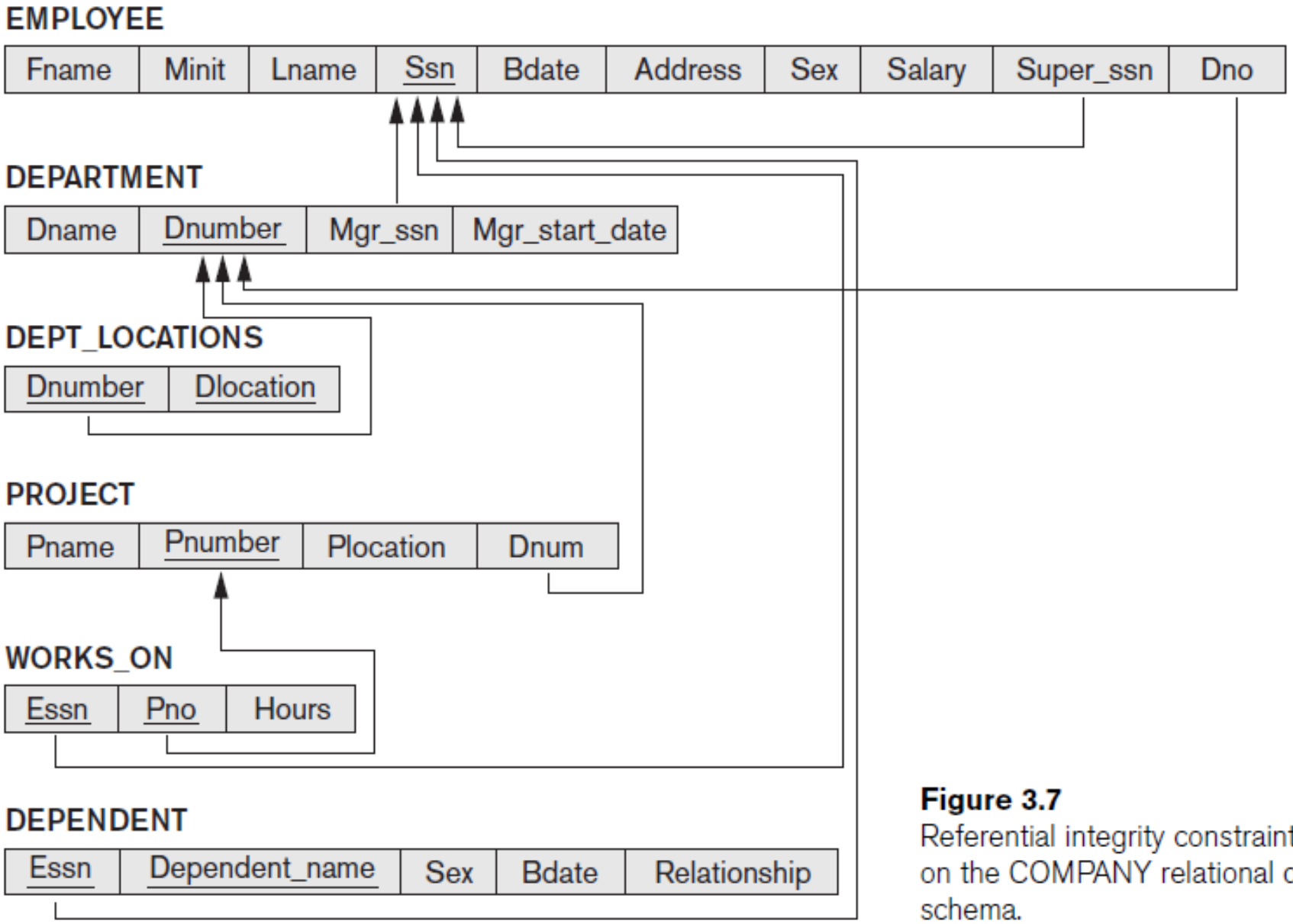


Figure 3.7
Referential integrity constraints displayed on the COMPANY relational database schema.

The Insert Operation

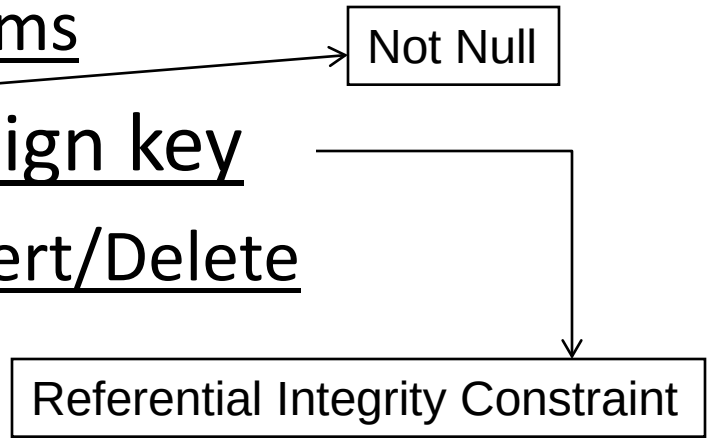
- Provides a list of attribute values for a new tuple *t* that is to be inserted into a relation R
- Can violate any of the four types of constraints
- If an insertion violates one or more constraints
  - Default option is to reject the insertion

The Delete Operation

- Can violate (ขัดแย้ง) only referential integrity
  - If tuple being deleted is referenced by foreign keys from other tuples
  - **Restrict**
    - Reject the deletion
  - **Cascade**
    - Propagate the deletion by deleting tuples that reference the tuple that is being deleted
  - **Set null** or **set default**
    - Modify the referencing attribute values that cause the violation

The Update Operation

- Necessary to specify a condition on attributes of relation
  - Select the tuple (or tuples) to be modified
- If attribute not part of a primary key nor of a foreign key
  - Usually causes no problems
- Updating a primary/foreign key
  - Similar issues as with Insert/Delete



The Transaction Concept

- **Transaction**
  - Executing program
  - Includes some database operations
  - Must leave the database in a valid or consistent state
- **Online transaction processing (OLTP) systems**
  - Execute transactions at rates that reach several hundred per second

Summary

- Characteristics differentiate relations from ordinary tables or files
- Classify database constraints into:
  - Inherent model-based constraints, explicit schema-based constraints, and application-based constraints
- Modification operations on the relational model:
  - Insert, Delete, and Update