

204320 - Database Management

Chapter 3

The Relational Data Model and Relational Database Constraints

Adapted for 204320

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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

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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

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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*

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Relational Model Concepts (cont'd.)

| Relation Name | | Attributes | | | | | | |
|---------------|----------------|-------------|---------------|----------------------|---------------|--------------|------|-----|
| STUDENT | | Name | Ssn | Home_phone | Address | Office_phone | Age | Gpa |
| Tuples | 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.

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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

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

- **Relation schema R**
 - Denoted by $R(A_1, A_2, \dots, A_n)$
 - Made up of a relation name R and a list of attributes, A_1, A_2, \dots, A_n
 - Relation schema ประกอบด้วย ชื่อ relation R และ attributes A_1, A_2, \dots, A_n ของ R
 - แต่ละ Relation อยู่ในรูป $R(A_1, A_2, \dots, A_n)$
- **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

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

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

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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

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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 |
| Chung-cha Kim | 381-62-1245 | (817)375-4409 | 125 Kirby Road | NULL | 18 | 2.89 |
| Benjamin Bayer | 305-61-2435 | (817)373-1616 | 2918 Bluebonnet Lane | NULL | 19 | 3.21 |

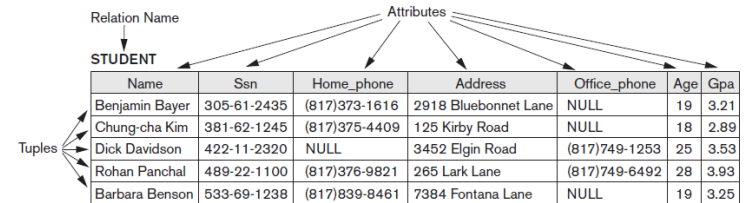


Figure 3.1

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

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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 หรือ ณ ขณะนั้นยังไม่ทราบ)
 - *Attribute does not apply to this tuple (also known as value undefined)* ไม่ได้กำหนด

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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)

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Relational Model Notation

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

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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)

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Relational Model Notation

- n -tuple t in a relation $r(R)$
 - Denoted by $t = \langle v_1, v_2, \dots, v_n \rangle$
 - 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
 - $t[A_u, A_w, \dots, A_z]$ and $t.(A_u, A_w, \dots, A_z)$ refer to the subtuple of values $\langle v_u, v_w, \dots, v_z \rangle$ from t corresponding to the attributes specified in the list

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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

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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

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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

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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

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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

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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**

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

CAR

| <u>License_number</u> | <u>Engine_serial_number</u> | 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 $S = \{R_1, R_2, \dots, R_m\}$
 - Set of Integrity Constraints (IC)
- **Relational database state**
 - Set of relation states $DB = \{r_1, r_2, \dots, r_m\}$
 - Each r_i is a state of R_i and such that the r_i relation states satisfy integrity constraints specified in IC

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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

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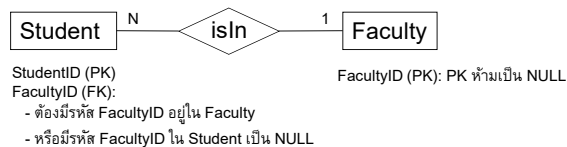
Integrity, Referential Integrity, and Foreign Keys

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

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

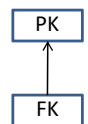
- **Foreign key rules:**
 - The attributes in FK have the same domain(s) as the primary key attributes PK
 - Value of FK in a tuple t_1 of the current state $r_1(R_1)$ either occurs as a value of PK for some tuple t_2 in the current state $r_2(R_2)$ or is NULL



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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



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Other Types of Constraints

- Semantic integrity constraints
 - May have to be specified and enforced on a relational database
 - Use **triggers**: เมื่อมีเหตุการณ์ที่ทำให้ข้อมูลมีการ Insert Update Delete เกิดขึ้นในฐานข้อมูล จะกระตุ้นให้ DBMS ทำอะไรบางอย่าง
 - **assertions**: คำสั่งที่ใช้ในการตรวจสอบความถูกต้องของข้อมูล
 - 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

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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

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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)

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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 |

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

| WORKS_ON | | | PROJECT | | | |
|-----------|-----|-------|-----------------|---------|-----------|------|
| Essn | Pno | Hours | Pname | Pnumber | Plocation | Dnum |
| 123456789 | 1 | 32.5 | ProductX | 1 | Bellaire | 5 |
| 123456789 | 2 | 7.5 | ProductY | 2 | Sugarland | 5 |
| 666884444 | 3 | 40.0 | ProductZ | 3 | Houston | 5 |
| 453453453 | 1 | 20.0 | Computerization | 10 | Stafford | 4 |
| 453453453 | 2 | 20.0 | Reorganization | 20 | Houston | 1 |
| 333445555 | 2 | 10.0 | Newbenefits | 30 | Stafford | 4 |
| 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 | | | | |

| 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 |

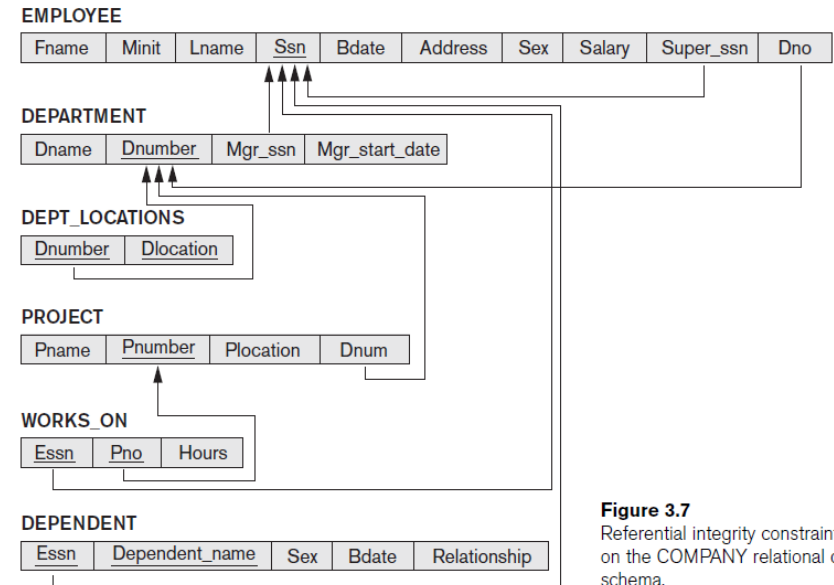


Figure 3.7
Referential integrity constraints displayed on the COMPANY relational database schema.

The Insert Operation

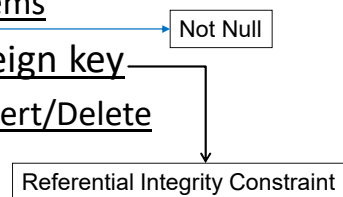
- Provides a list of attribute values for a new tuple t that is to be inserted into a relation R
- Can violate any of the four types of constraints
- If an insertion violates one or more constraints
 - Default option is to reject the insertion

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



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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

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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

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