UNIVERSITAS INDONESIA

FAKULTAS ILMU KOMPUTER

Slide 5

The Relational Data Model and Relational Database Constraints

CSF2600700 - BASIS DATA

SEMESTER GANJIL 2019/2020

Reference:
"Database System", 7th edition, Elmasri/Navathe, 2011:
Chapter 5 The Relational Data Model and Relational Database Constraints

Outline

Relational Model Concept

Characteristics of Relations

Relational Model Notation

Relational Model Constraints

Update Operations, Transactions, and Dealing with Constraint Violations

The Relational Data Model

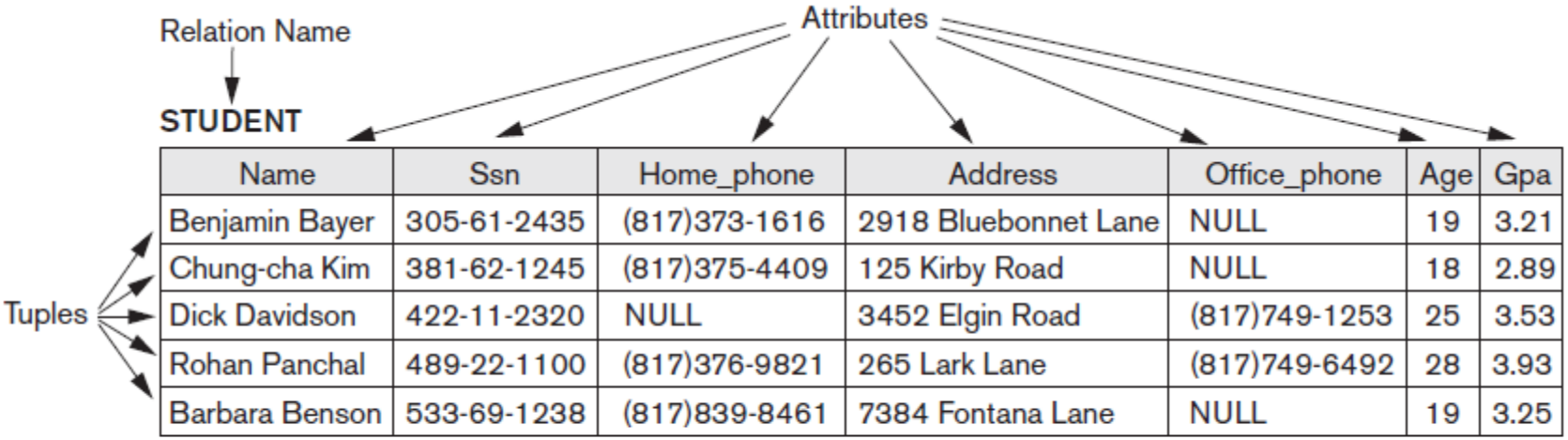
Relational model

- Introduced by Ted Codd of IBM Research in 1970
- The model uses the concept of a mathematical relation
- First commercial implementations available in early 1980s by IBM and Oracle
- Has been implemented in a large number of commercial system
- Popular Relational DBMS: Oracle, DB2, MySQL, PostgreSQL
- Preceded by hierarchical and network models

Relational Model Concepts

- Represents database as a collection of relations
- Each relation resembles a **table** of values
  - Row
    - Represents a collection of related data values
    - Represents a fact that typically corresponds to a real-world entity or relationship
  - Table name and column names
    - Interpret the meaning of the values in each row
  - *Formal Terminology*
    - *Row → Tuple*
    - *Column header → attribute*
    - *Table → Relation*

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 values
- Example:
  - GPA: real number between 0 and 4
  - Local_phone_numbers. The set of seven-digit phone numbers valid within a particular area code

Atomic

- Each value indivisible

Specifying a domain

- **Data type** specified for each domain

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
  - Example: STUDENT(Name, SSN, Home_phone, Address, Office_phone, Age, Gpa)
- 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
  - STUDENT: a relation of degree 7

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

Relation (or **relation state**)

- 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
- Example:
  - t = <'Benyamin Bayer', '305-61-2435', …, 3.21>

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

Relation (or relation state) $r(R)$

- **Mathematical relation** of degree n on the domains $\text{dom}(A_1)$, $\text{dom}(A_2)$, ..., $\text{dom}(A_n)$
- **Subset** of the **Cartesian product** of the domains that define R:
  - $r(R) \subseteq (\text{dom}(A_1) \times \text{dom}(A_2) \times ... \times \text{dom}(A_n))$
- The **Cartesian product** specifies all possible combinations of values from the underlying domains.

Example

Given relation schema $R(A_1, A_2)$

- dom(A_1) = {0,1}
- dom(A_2) = {a,b,c}

Cartesian product of the domain → dom (A_1) X dom (A_2):

{<0,a> , <0,b> , <0,c>, <1,a>, <1,b>, <1,c> }

A *state* of R:

{<0,a> , <1,a>, <1,c> }

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

Cardinality

- Total number of values in domain

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

Equivalent Terminology

Formal (Relational Model)	Non Formal
Relation	Table (File)
Tuple	Row (Record)
Attribute	Column Header (Field)
Domain	All possible column values
Schema of a relation	Table definition
State of the relation	Populated table

Outline

The Relational Data Model

Characteristics of Relations

Relational Model Notation

Relational Model Constraints

Update Operations, Transactions, and Dealing with Constraint Violations

Characteristics of Relations

Ordering of tuples in a relation

- Relation defined as a set of tuples
- Elements have no order among them

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

Characteristics of Relations

Ordering of values within a tuple

- Order of attributes and values is not that important
- As long as correspondence between attributes and values maintained

Alternative definition of a relation

- Tuple considered as a set of (<attribute>, <value>) pairs
- Each pair gives the value of the mapping from an attribute A_i to a value v_i from dom(A_i)

Characteristics of Relations (cont'd.)

Figure 3.3
Two identical tuples when the order of attributes and values is not part of relation definition.

$t = <$ (Name, Dick Davidson),(Ssn, 422-11-2320),(Home_phone, NULL),(Address, 3452 Elgin Road),
(Office_phone, (817)749-1253),(Age, 25),(Gpa, 3.53)>

$t = <$ (Address, 3452 Elgin Road),(Name, Dick Davidson),(Ssn, 422-11-2320),(Age, 25),
(Office_phone, (817)749-1253),(Gpa, 3.53),(Home_phone, NULL)>

Use the first definition of relation

- Attributes and the values within tuples are ordered
- Simpler notation

Characteristics of Relations (cont'd.)

Values in tuples

- Each value in a tuple is atomic
- **Flat relational model**
  - Composite and multivalued attributes not allowed
  - **First normal form** assumption
- Multivalued attributes
  - Example: Favourite color = {red, green}
  - Must be represented by separate relations
- Composite attributes
  - Example: Address can be divided into Street_address, City, State, Zip.
  - 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*
  - *Attribute does not apply to this tuple (also known as value undefined)*

Exercise

From the following tables, which one is a relation in a relational database?

R1

A	B	C	D
a2	{b1, b2}	c1	d5
a2	b7	c9	d5
a2	b23	c22	d1
.....			

R2

A	B	C	D
a2	b2	c6	d1
a2	b7	c9	d5
a2	b7	c9	d5
.....			

R3

E#	Ename	AGE	ADDRESS
E2	Diamond	45	1888 Buford Hyw.
E1	Smith	30	3302 Peachtree Rd., Atlanta, GA
E3	Evan	null	Baker Ct. Atlanta

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Relational Model Notation

Relation schema R of degree n

- 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

Letters t, u, v

- Denote tuples

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*

Relational Model Notation

n-tuple t in a relation $r(R)$

- Denoted by $t = <v_1, v_2, ..., v_n>$
- 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
- $t[A_u, A_w, ..., A_z]$ and $t.(A_u, A_w, ..., A_z)$ refer to the subtuple of values $<v_u, v_w, ..., v_z>$ from t corresponding to the attributes specified in the list

Example:

the tuple t = <'Barbara Benson', '533-69-1238', '(817)839-8461', '7384 Fontana Lane', NULL, 19, 3.25> from the STUDENT relation

t[Name] = <'Barbara Benson'>, and t[Ssn, Gpa, Age] = <'533-69-1238', 3.25, 19>.

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Relational Model Constraints

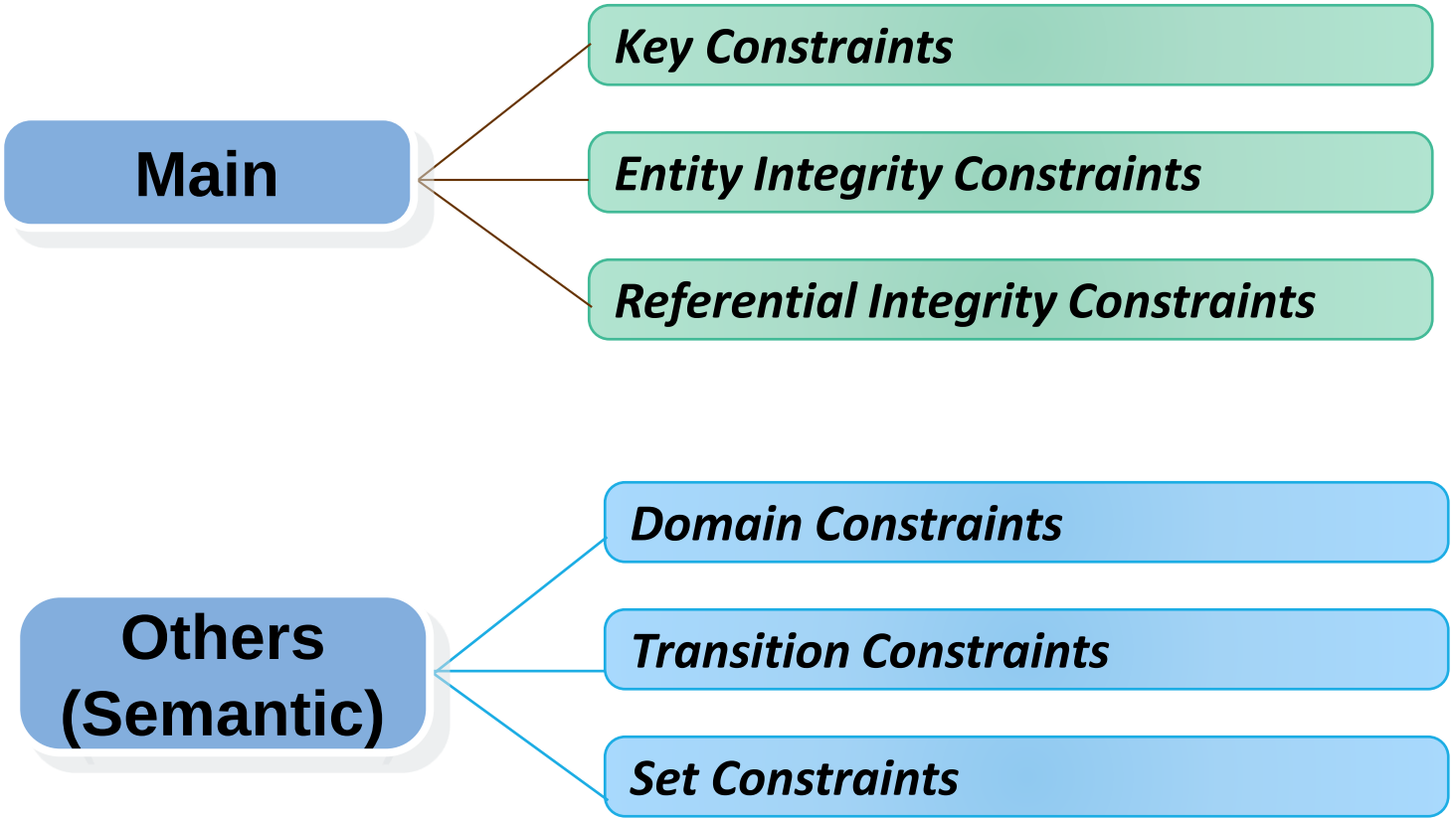
Constraints

- Restrictions on the actual values in a database state
- Derived from the rules in the miniworld that the database represents

Constraints Categories:

- **Inherent model-based constraints** or **implicit constraints**
  - Inherent in the data model
- **Schema-based constraints** or **explicit constraints**
  - Can be directly expressed in schemas of the data model or in DDL
- **Application-based** or **semantic constraints** or **business rules**
  - Cannot be directly expressed in schemas
  - Expressed and enforced by application program

Classification of *Relational Integrity Constraints*



Domain Constraints

Specify that within each tuple, the value of each attribute A must be an atomic value from the domain dom(A)

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

Key Constraints

- No two tuples can have the same combination of values for all their attributes.

Superkey (SK)

- SK: an attribute or set of attributes that guarantee that no two distinct tuples in any state *r* of *R* can have the same value for SK

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

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 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 / alternate 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.

Example

SSN	FName	LName	BirthDate	Sex	Address
0606007800	Ahmad	Zakky	10-4-87	L	Jakarta
0607001123	Gede	Saraswati	19-9-87	P	Denpasar
0607120012	Bayu	Wirawan	12-12-86	L	Jimbaran
0607121023	Satya	Wirawan	12-12-86	L	Jimbaran
0607131240	Fira	Bahira	1-3-87	P	Jakarta
0607132222	Nayla	Putri	1-9-86	P	Depok

Super key:
SSN,
{SSN, Lname},
{FName, BirthDate},
{FName, Sex},
...

Candidate key:
SSN,
FName

Primary Key:
SSN

Alternate Key:
FName

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

Constraints on NULL Value

- For an attribute, we can specify whether NULL values are or are not permitted
- For example: every STUDENT tuple must have a valid, non-NULL value for the Name attribute → then Name of STUDENT is constraint to be NOT NULL

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.)

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

Figure 3.5
Schema diagram for the COMPANY relational database schema.

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

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.)

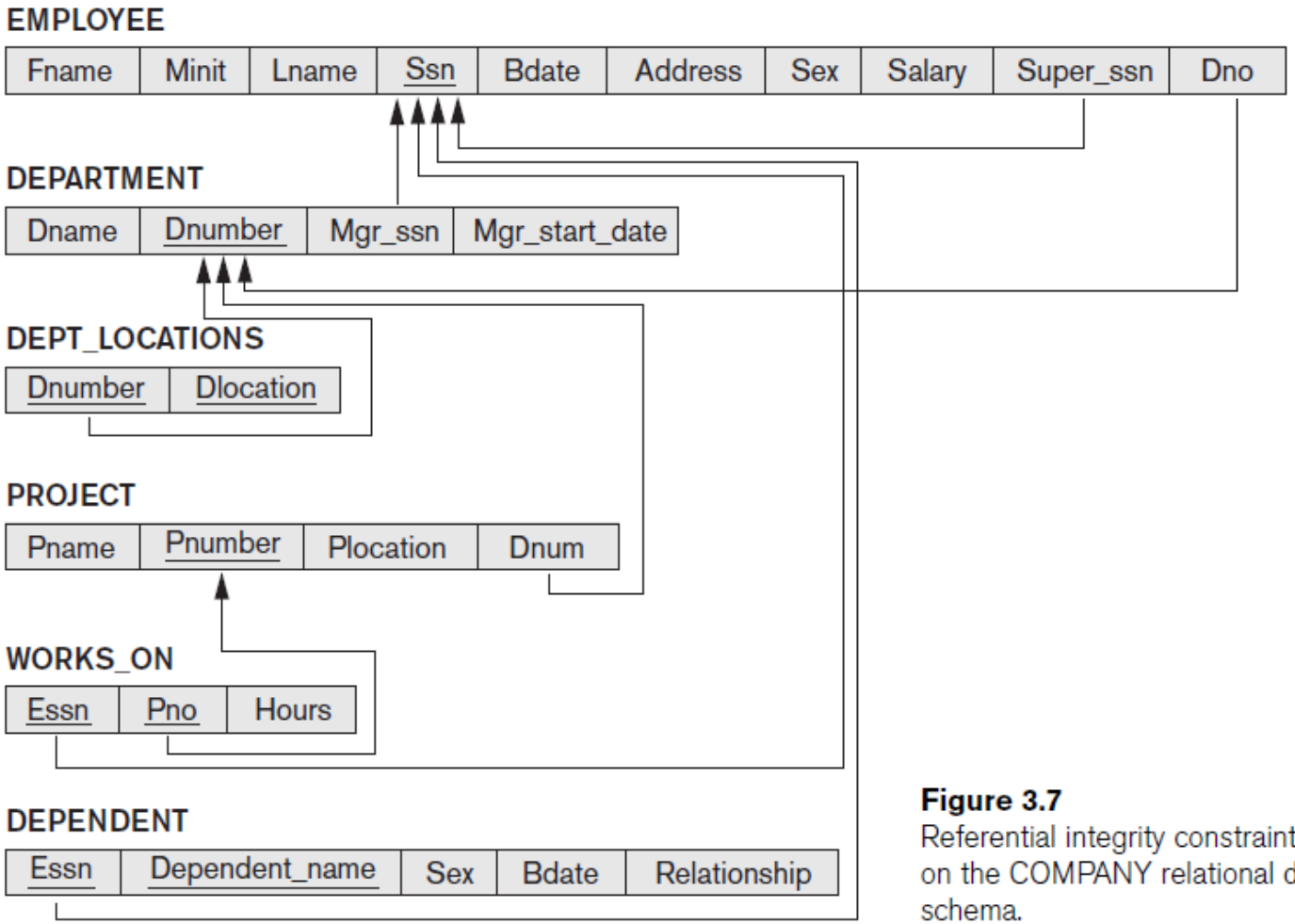


Figure 3.7
Referential integrity constraints displayed on the COMPANY relational database schema.

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** and **assertions**
- More common to check for these types of constraints within the application programs

Latihan

Basis data yang memproses *order* (pemesanan) pada sebuah perusahaan memiliki 6 relasi berikut:

CUSTOMER (Cust#, Cname, City)
ORDER (Order#, Odate, Cust#, Ord_Amt)
ORDER_ITEM (Order#, Item#, Qty)
ITEM (Item#, Unit_price)
SHIPMENT (Order#, Warehouse#, Ship_date)
WAREHOUSE (Warehouse#, City)

Ord_Amt mengacu pada jumlah harga pada satu kali *order*. **Odate** menyatakan tanggal pemesanan dilakukan, **Ship_date** menyatakan tanggal pengiriman barang yang dipesan *customer* dari gudang. Asumsikan bahwa suatu *order* dapat mengambil barang dari beberapa gudang (**warehouse**). Nyatakan ***foreign key*** yang mungkin untuk skema basis data ini.

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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)

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
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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

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 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

Latihan

Figure 5.6
One possible database state for the COMPANY relational database schema.

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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

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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

Apakah ada *constraints* yang dilanggar pada operasi berikut?

1. Insert < 'ProductA', 4, 'Bellaire', 2 > into PROJECT.
2. Insert < '677678989', null, '40.0' > into WORKS_ON.
3. Delete the WORKS_ON tuples with ESSN= '333445555'.
4. Delete the EMPLOYEE tuple with SSN= '987654321'.
5. Modify the SUPERSSN attribute of the EMPLOYEE tuple with SSN= '999887777' to '943775543'.

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

FINISH