

CSI 2132 Tutorial 3

From the Conceptual
to the Relational Model

“The Enhanced ER Model”

EER Model

- Extension to ER model that improves its representational capabilities.
- Subclasses and Superclasses
- **Specialization** and **Generalization**
 - *Top-down refinement*
 - *Bottom-up synthesis*
- Attribute and Relationship Inheritance

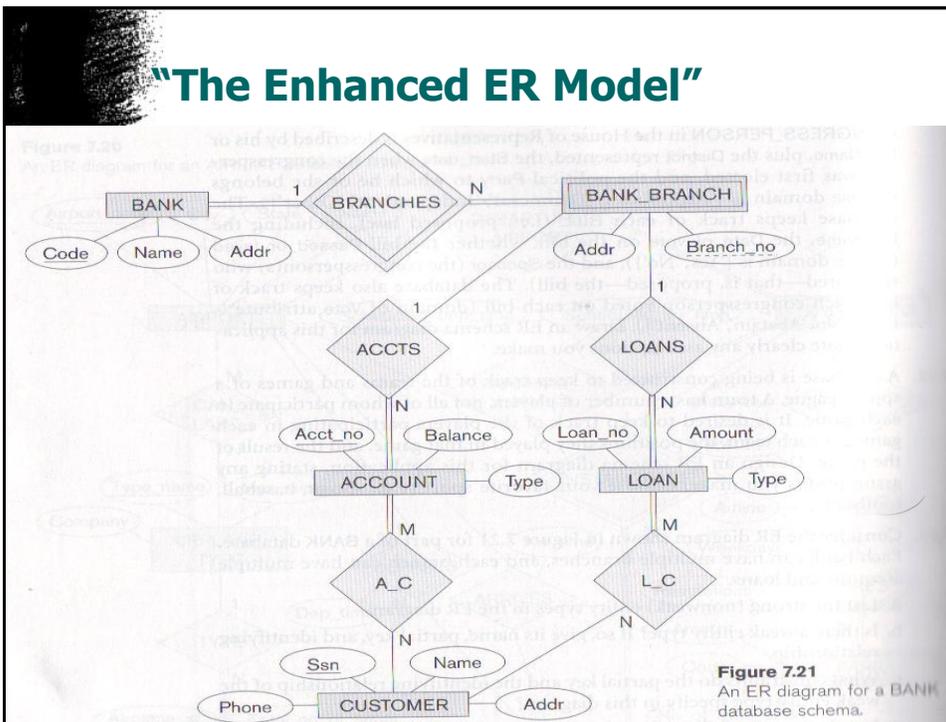
"The Enhanced ER Model"

Exercise 1:

Consider following BANK ER schema:

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"The Enhanced ER Model"



"The Enhanced ER Model"

Exercise 1:

Suppose that it is necessary to keep track of different types of **accounts** (SAVINGS, CHECKING, ...) and **LOANS** (CAR_LOANS, HOME_LOANS, ...).

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"The Enhanced ER Model"

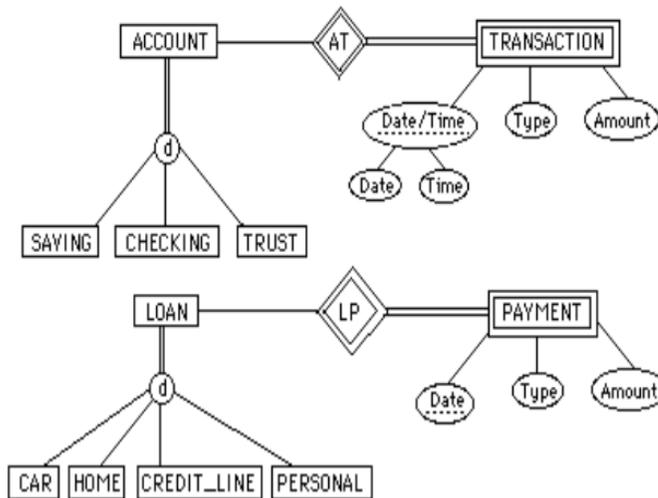
Exercise 1:

Suppose that it is also desirable to keep track of each account's **transactions** (deposits, withdrawals, checks, ...) and each loan's **payment**; both of these include the amount, date, time, ...

Modify the BANK schema, using ER and EER concepts of **specialization** and **generalization**. State any assumptions you make about the additional requirements.

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"The Enhanced ER Model"



"The Relational Data Model and Relational Database Constraints"

Types of Integrity Constraints (Ensure **Integrity of our data**):

- Entity Integrity (or key) constraint.
 - No PK has a NULL value
 - No instances with PK repeated
 - Maintains **identifiable** each tuple
- Referential integrity constraint.
 - FK either NULL or matches a PK
 - Maintains **consistency** in data
- General Constraints.
 - Functional Dependency constraints
 - State constraints
 - Transition Constraints

"The Relational Data Model and Relational Database Constraints"

Exercise 2:

Suppose each of the following Update operations is applied directly to the following database. Discuss *all* integrity constraints violated by each operation, if any, and the different ways of enforcing these constraints.

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"The Relational Data Model and Relational Database Constraints"

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	1965-12-08	838 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zalaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellare, 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	Bellare
5	Sugarland
5	Houston

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	Bellare	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	1985-04-05	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

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"The Relational Data Model and Relational Database Constraints"

Empno	Empname	Job	Mgr Empno	Start Date	Address	Sex	Salary	Dept No	Project No	Project Name	Project Location	Project Drum	Dependent Name	Relationship
123456789	John B Smith	Analyst	333445555	1985-01-09	731 Fondren, Houston, TX	M	30000	5	1	ProductX	Bellaire	5	Alice	Daughter
123456789	Franklin T Wong	Analyst	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	5	2	ProductY	Sugarland	5	Theodore	Son
123456789	Alicia J Zelaya	Analyst	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	4	3	ProductZ	Houston	5	Joy	Spouse
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123456789	Ramesh K Narayan	Analyst	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	5	20	Reorganization	Houston	1	Michael	Son
123456789	Joyce A English	Analyst	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	5	30	Newbenefits	Stafford	4	Alice	Daughter
123456789	Ahmad V Jabbar	Analyst	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	4	30	Newbenefits	Stafford	4	Elizabeth	Spouse
123456789	James E Borg	Analyst	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	1						

Exercise 2:

First we need to identify the relationships

Employee SSN

Department number

Project number

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"The Relational Data Model and Relational Database Constraints"

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Exercise 2

(A) .Insert:

< 'Robert', 'F', 'Scott',
'943775543', '21-JUN-42',
'2365 Newcastle Rd, Bellaire,
TX', M, 58000, '888665555',
1 >

into **EMPLOYEE**.

No constraint violations

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"The Relational Data Model and Relational Database Constraints"

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Exercise 2

(B) **.Insert**

< 'ProductA', 4, 'Bellaire', 2 >
into **PROJECT**

Violates referential integrity because there is no tuple in the **DEPARTMENT** relation with **DNUMBER=2**.

- Reject the insertion
- Change the value of **DNUM**
- Insert a new **DEPARTMENT** with **DNUMBER=2**

13

"The Relational Data Model and Relational Database Constraints"

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Exercise 2

(C) **.Insert**

< 'Production', 4, '943775543', '01-OCT-88' >
into **DEPARTMENT**

Violates key constraint because there already exists **DNUMBER=4**.

- Reject the insertion
- Change the **DNUMBER**

Violates referential integrity because there is no tuple in the **EMPLOYEE** relation with **SSN = '943775543'**.

- Reject the insertion
- Change the value of **MGRSSN**
- Insert a new **EMPLOYEE** with **SSN='943775543'**

14

"The Relational Data Model and Relational Database Constraints"

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Exercise 2

(D) **.Insert**

< '677678989', null, '40.0' >
into **WORKS_ON**

Violates entity integrity because PNO, which is part of the primary key of WORKS_ON, is null.

- (i) Reject the insertion
- (ii) Change the value of PNO.

Violates referential integrity because there is no tuple in the EMPLOYEE relation with SSN='677678989'.

- (i) Reject the insertion
- (ii) Change the value of ESSN
- (iii) Inserting a new EMPLOYEE tuple with SSN='677678989'

15

"The Relational Data Model and Relational Database Constraints"

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No constraint violations

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"The Relational Data Model and Relational Database Constraints"

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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	<table border="1"> <thead> <tr> <th>Dname</th> <th>Dnumber</th> <th>Mgr_ssn</th> <th>Mgr_start_date</th> </tr> </thead> <tbody> <tr><td>Research</td><td>5</td><td>333445555</td><td>1988-05-22</td></tr> <tr><td>Administration</td><td>4</td><td>987654321</td><td>1995-01-01</td></tr> <tr><td>Headquarters</td><td>1</td><td>888665555</td><td>1981-06-19</td></tr> </tbody> </table>	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	<table border="1"> <thead> <tr> 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<tr><td>Reorganization</td><td>20</td><td>Houston</td><td>1</td></tr> <tr><td>Newbenefits</td><td>30</td><td>Stafford</td><td>4</td></tr> </tbody> </table>	Pname	Pnumber	Plocation	Pmgr	ProductX	1	Bellaire	5	ProductY	2	Sugarland	5	ProductZ	3	Houston	5	Computerization	10	Stafford	4	Reorganization	20	Houston	1	Newbenefits	30	Stafford	4	<table border="1"> <thead> <tr> <th>Essn</th> <th>Dependent_name</th> <th>Sex</th> <th>Bdate</th> <th>Relationship</th> </tr> </thead> <tbody> <tr><td>333445555</td><td>Alice</td><td>F</td><td>1986-04-05</td><td>Daughter</td></tr> <tr><td>333445555</td><td>Theodore</td><td>M</td><td>1983-10-25</td><td>Son</td></tr> <tr><td>333445555</td><td>Joy</td><td>F</td><td>1958-05-03</td><td>Spouse</td></tr> <tr><td>987654321</td><td>Abner</td><td>M</td><td>1942-02-28</td><td>Spouse</td></tr> <tr><td>123456789</td><td>Michael</td><td>M</td><td>1988-01-04</td><td>Son</td></tr> <tr><td>123456789</td><td>Alice</td><td>F</td><td>1988-12-30</td><td>Daughter</td></tr> 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Exercise 2

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ESSN= '333445555'

No constraint violations

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Exercise 2

(G) .Delete the EMPLOYEE tuple with

SSN= '987654321'

Violates referential integrity because there are tuples existing in the WORKS_ON, DEPENDENT, DEPARTMENT, and EMPLOYEE that reference the value being deleted from EMPLOYEE.

- (i) Reject the deletion
- (ii) Delete all tuples in the WORKS_ON, DEPENDENT, DEPARTMENT, and EMPLOYEE whose values for ESSN, MGRSSN, and SUPERSSN is '987654321'

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Exercise 2

- (H) .Delete the PROJECT tuple with
PNAME= 'ProductX'

Violates referential integrity because two tuples exist in the WORKS_ON that reference the tuple being deleted

- (i) Reject the deletion
(ii) Delete the tuples in the WORKS_ON where value for PNO=1.

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"The Relational Data Model and Relational Database Constraints"

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Exercise 2

- (I) .Modify the MGRSSN and MGRSTARTDATE of the DEPARTMENT tuple with DNUMBER=5 to '123456789' and '01-OCT-88', respectively

No constraint violations

20

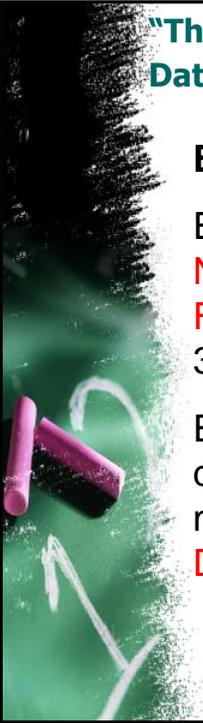


"The Relational Data Model and Relational Database Constraints"

Exercise 3

Consider the following AIRLINE relational database schema. Which describes a database for airline flight information.

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"The Relational Data Model and Relational Database Constraints"

Exercise 3

Each **FLIGHT** is identified by a flight **NUMBER** and consists of one or more **FLIGHT_LEGs** with **LEG_NUMBERS** 1, 2, 3, etc.

Each leg has scheduled arrival and departure times and airports, and has many **LEG_INSTANCES**--one for each **DATE** on which the flight travels.

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"The Relational Data Model and Relational Database Constraints"

Exercise 3

FARES are kept for each flight.

For each leg instance, **SEAT_RESERVATIONS** are kept, as is the **AIRPLANE** used in the leg, and the actual arrival and departure times and airports.

An **AIRPLANE** is identified by an **AIRPLANE_ID**, and is of a particular **AIRPLANE_TYPE**.

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"The Relational Data Model and Relational Database Constraints"

Exercise 3

CAN_LAND relates **AIRPLANE_TYPES** to the **AIRPORTS** in which they can land. An **AIRPORT** is identified by an **AIRPORT_CODE**.

Consider an update for the **AIRLINE** database to enter a reservation on a particular flight or flight leg on a given date.

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"The Relational Data Model and Relational Database Constraints"

AIRPORT			
Airport_code	Name	City	State

FLIGHT		
Flight_number	Airline	Weekdays

FLIGHT_LEG			
Flight_number	Leg_number	Departure_airport_code	Scheduled_departure_time
		Arrival_airport_code	Scheduled_arrival_time

LEG_INSTANCE				
Flight_number	Leg_number	Date	Number_of_available_seats	Airplane_id
		Departure_airport_code	Departure_time	Arrival_airport_code
				Arrival_time

FARE			
Flight_number	Fare_code	Amount	Restrictions

AIRPLANE_TYPE		
Airplane_type_name	Max_seats	Company

CAN_LAND	
Airplane_type_name	Airport_code

AIRPLANE		
Airplane_id	Total_number_of_seats	Airplane_type

SEAT_RESERVATION					
Flight_number	Leg_number	Date	Seat_number	Customer_name	Customer_phone

Exercise 3

(A) Give the operations for this **update**.

Enter a reservation on a particular flight on a given date

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"The Relational Data Model and Relational Database Constraints"

Exercise 3 (A)

- **INSERT**

<FNO,LNO,DT,SEAT_NO,CUST_NAME
,CUST_PHONE>

into SEAT_RESERVATION

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"The Relational Data Model and Relational Database Constraints"

Exercise 3 (A)

- **MODIFY** the LEG_INSTANCE tuple with the condition:
 - *(FLIGHT_NUMBER=FNO AND LEG_NUMBER=LNO AND DATE=DT)* by setting
 - **NUMBER_OF_AVAILABLE_SEATS = NUMBER_OF_AVAILABLE_SEATS - 1**

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"The Relational Data Model and Relational Database Constraints"

Exercise 3 (A)

- These operations should be repeated for each LEG of the flight on which a reservation is made.
- This assumes that the reservation has only one seat.

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"The Relational Data Model and Relational Database Constraints"

AIRPORT				
Airport_code	Name	City	State	

FLIGHT		
Flight_number	Airline	Weekdays

FLIGHT_LEG				
Flight_number	Leg_number	Departure_airport_code	Scheduled_departure_time	
			Arrival_airport_code	Scheduled_arrival_time

LEG_INSTANCE				
Flight_number	Leg_number	Date	Number_of_available_seats	Airplane_id
		Departure_airport_code	Departure_time	Arrival_airport_code
		Arrival_time		

FARE			
Flight_number	Fare_code	Amount	Restrictions

AIRPLANE_TYPE		
Airplane_type_name	Max_seats	Company

CAN_LAND	
Airplane_type_name	Airport_code

AIRPLANE		
Airplane_id	Total_number_of_seats	Airplane_type

SEAT_RESERVATION					
Flight_number	Leg_number	Date	Seat_number	Customer_name	Customer_phone

Exercise 3

- (B) What types of **constraints** would you expect to check?.

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"The Relational Data Model and Relational Database Constraints"

Exercise 3 (B)

- We would check that

- **NUMBER_OF_AVAILABLE_SEATS** on each **LEG_INSTANCE** of the flight is greater than 1 before doing any reservation.
- That the **SEAT_NUMBER** being reserved in **SEAT_RESERVATION** is available.

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"The Relational Data Model and Relational Database Constraints"

AIRPORT			
Airport_code	Name	City	State

FLIGHT		
Flight_number	Airline	Weekdays

FLIGHT_LEG			
Flight_number	Leg_number	Departure_airport_code	Scheduled_departure_time
		Arrival_airport_code	Scheduled_arrival_time

LEG_INSTANCE				
Flight_number	Leg_number	Date	Number_of_available_seats	Airplane_id
		Departure_airport_code	Departure_time	Arrival_airport_code
				Arrival_time

FARE			
Flight_number	Fare_code	Amount	Restrictions

AIRPLANE_TYPE		
Airplane_type_name	Max_seats	Company

CAN_LAND	
Airplane_type_name	Airport_code

AIRPLANE		
Airplane_id	Total_number_of_seats	Airplane_type

SEAT_RESERVATION					
Flight_number	Leg_number	Date	Seat_number	Customer_name	Customer_phone

Exercise 3

- (C) Which of these constraints are **key**, **entity integrity**, and **referential integrity constraints** and which are not?.

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"The Relational Data Model and Relational Database Constraints"

Exercise 3 (C)

- The INSERT operation into SEAT_RESERVATION will check all the key, entity integrity and referential integrity constraints for the relation.
- Check that NUMBER_OF_AVAILABLE_SEATS on each LEG_INSTANCE of the flight is greater than 1 does not fall into any of the above types of constraints.

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"The Relational Data Model and Relational Database Constraints"

AIRPORT				
Airport_code	Name	City	State	
FLIGHT				
Flight_number	Airline	Weekdays		
FLIGHT_LEG				
Flight_number	Leg_number	Departure_airport_code	Scheduled_departure_time	
		Arrival_airport_code	Scheduled_arrival_time	
LEG_INSTANCE				
Flight_number	Leg_number	Date	Number_of_available_seats	Airplane_id
		Departure_airport_code	Departure_time	Arrival_airport_code
			Arrival_time	
FARE				
Flight_number	Fare_code	Amount	Restrictions	
AIRPLANE_TYPE				
Airplane_type_name	Max_seats	Company		
CAN_LAND				
Airplane_type_name	Airport_code			
AIRPLANE				
Airplane_id	Total_number_of_seats	Airplane_type		
SEAT_RESERVATION				
Flight_number	Leg_number	Date	Seat_number	Customer_name
				Customer_phone

Exercise 3

- (D) Specify all the **referential integrity constraints**.

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"The Relational Data Model and Relational Database Constraints"

Exercise 3 (D)

- We will write a **referential integrity constraint** as:
 - $R.A \twoheadrightarrow S$
 - OR
 - $R.(X) \twoheadrightarrow S$

Whenever attribute A (or the set of attributes X) of relation R form a foreign key that references the primary key of relation S.

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"The Relational Data Model and Relational Database Constraints"

Exercise 3 (D)

- **FLIGHT_LEG.FLIGHT_NUMBER --> FLIGHT**
- **FLIGHT_LEG.DEPARTURE_AIRPORT_CODE --> AIRPORT**
- **FLIGHT_LEG.ARRIVAL_AIRPORT_CODE --> AIRPORT**
- **LEG_INSTANCE.(FLIGHT_NUMBER, LEG_NUMBER) --> FLIGHT_LEG**

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"The Relational Data Model and Relational Database Constraints"

Exercise 3 (D)

- **LEG_INSTANCE.DEPARTURE_AIRPORT_CODE --> AIRPORT**
- **LEG_INSTANCE.ARRIVAL_AIRPORT_CODE --> AIRPORT**
- **LEG_INSTANCE.AIRPLANE_ID --> AIRPLANE**
- **FARES.FLIGHT_NUMBER --> FLIGHT**
- **CAN_LAND.AIRPLANE_TYPE_NAME -> AIRPLANE_TYPE**

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"The Relational Data Model and Relational Database Constraints"

Exercise 3 (D)

- CAN_LAND.AIRPORT_CODE --> AIRPORT
- AIRPLANE.AIRPLANE_TYPE --> AIRPLANE_TYPE
- SEAT_RESERVATION.(FLIGHT_NUMBER, LEG_NUMBER, DATE) --> LEG_INSTANCE

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"The Relational Data Model and Relational Database Constraints"

Exercise 4

- Consider the following relations for a database that keeps track of business trips of salespersons in a sales office:
 - SALESPERSON (*SSN, Name, Start_Year, Dept_No*)
 - TRIP (*SSN, From_City, To_City, Departure_Date, Return_Date, Trip_ID*)
 - EXPENSE (*Trip_ID, Account#, Amount*)
- Specify the **foreign keys** for this schema, stating any assumptions you make.

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"The Relational Data Model and Relational Database Constraints"

Exercise 4

- The schema of this question has the following two foreign keys:
 - *The attribute SSN of relation TRIP that references relation SALESPERSON*
 - *The attribute Trip_ID of relation EXPENSE that references relation TRIP.*
- The attributes Dept_No of relation SALESPERSON and Account# of relation EXPENSE are probably also foreign keys referring to other tables not mentioned in the exercise.

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"The Relational Data Model and Relational Database Constraints"

Exercise 5

Database design often involves decisions about the storage of attributes.

For example a Social Security Number can be stored as a one attribute or split into three attributes (one for each of the three hyphen-delimited groups of numbers in a Social Security Number—XXX-XX-XXXX)

(Area code – group number – serial number).

However, Social Security Number is usually stored in one attribute. The decision is usually based on how the database will be used. This exercise asks you to think about specific situations where dividing the SSN is useful.

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"The Relational Data Model and Relational Database Constraints"

Exercise 5

- We need the area code (city code) and perhaps the country code (for dialing international phone numbers).
- It is recommended to store the numbers in separate attributes since they have their own independent existence and makes it easier to make any change.
 - *For example, if an area code region were split into two regions and we have the area code in a separate attribute, it will be easier to update it.*

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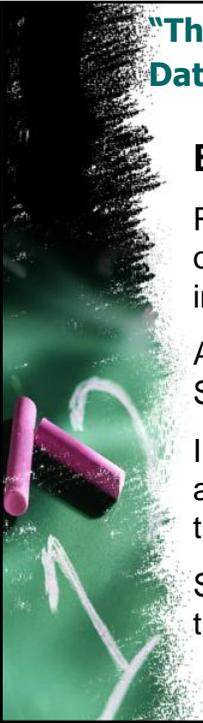


"The Relational Data Model and Relational Database Constraints"

Exercise 5

- It only makes sense to split the SSN into its component if we are going to use the subsequences to make deductions about validity, geography, etc.

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"The Relational Data Model and Relational Database Constraints"

Exercise 6

Recent changes in privacy laws have disallowed organizations from using SSN to identify individuals unless certain restrictions are satisfied.

As a result, most US universities cannot use SSNs as primary keys (except for financial data).

In practice, StudentID, a **unique ID identifier**, assigned to every student, is likely to be used as the primary key rather than SSN

Since StudentID is usable across all aspects of the system.

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"The Relational Data Model and Relational Database Constraints"

Exercise 6 (A)

Some database designers are reluctant to use generated keys (*surrogate* keys) for theStudentID because they are artificial.

Can you propose any **natural** choices of **keys** that can be used to store the student record in a UNIVERSITY database?.

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"The Relational Data Model and Relational Database Constraints"

Exercise 6 (A)

A combination of first name, last name, and home phone may address the issue assuming that there are no two students with identical names sharing a home phone line. It also assumes that every student has a home phone number.

Another solution may be to use first name, last name, and home zip code. This again has a potential for duplicates, which would be very rare within one university.

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"The Relational Data Model and Relational Database Constraints"

Exercise 6 (B)

Suppose that you were able to guarantee uniqueness of a natural key that included last name.

Are you guaranteed that the last name will not change during the lifetime of the database?

If the last name can change, what solutions can you propose for creating a primary key that still includes last name but **remains unique**?

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"The Relational Data Model and Relational Database Constraints"

Exercise 6 (B)

If we are using the name as the primary key and the name changes (maybe because she gets married), then we need to accept changes in the primary key as well (this is an example of how our database must be able to model the natural world)

Changing the primary key is acceptable, however we must have in mind that this can be inefficient since any references to this key in the database need to be appropriately updated, and this can take a long time.

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"The Relational Data Model and Relational Database Constraints"

Exercise 6 (C)

What are the **advantages** and **disadvantages** of using generated (surrogate) keys?

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"The Relational Data Model and Relational Database Constraints"

Exercise 6 (C)

Advantage of using a Surrogate Key

- *It gives us an invariant key without any worries about choosing a unique primary key.*

Disadvantages of using surrogate keys

- *They do not have a business meaning (making some aspects of database management challenging)*
- *They are slightly less efficient (because they require another pass when inserting a row to return the generated key to the application)*

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