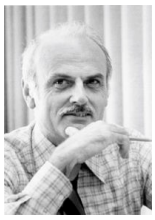
The Relational Data Model

Relational Model Concepts

- The relational Model of Data is based on the concept of a *Relation*.
- A Relation is a mathematical concept based on the ideas of sets.
- The strength of the relational approach to data management comes from the formal foundation provided by the theory of relations.

Relational Model Concepts

- The model was first proposed by Dr. E.F. Codd of IBM in 1970 in the following paper:
"A Relational Model for Large Shared Data Banks," Communications of the ACM, June 1970.



E F Codd (1923- 2003)

The above paper caused a major revolution in the field of Database management and earned Ted Codd the coveted ACM Turing Award.

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INFORMAL DEFINITIONS

RELATION: A table of values

- A relation may be thought of as a **set of rows**.
- A relation may alternately be thought of as a **set of columns**.
- Each row represents a fact that corresponds to a real-world **entity** or **relationship**.
- Each row has a value of an item or set of items that uniquely identifies that row in the table.
- Each column typically is called by its column name or column header or attribute name.

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FORMAL DEFINITIONS

- A **Relation** may be defined in multiple ways.
- The **Schema** of a Relation: *R* (A1, A2, ...An)
  Relation schema *R* is defined over **attributes**
  A1, A2, ...An
  For Example -
  CUSTOMER (Cust-id, Cust-name, Address, Phone#)

  Here, CUSTOMER is a relation defined over the four attributes Cust-id, Cust-name, Address, Phone#, each of which has a **domain** or a set of valid values. For example, the domain of Cust-id is 6 digit numbers.

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FORMAL DEFINITIONS

- A **tuple** is an ordered set of values
- Each value is derived from an appropriate domain.
- Each row in the CUSTOMER table may be referred to as a tuple in the table and would consist of four values.
- **<632895, "John Smith", "101 Main St. Atlanta, GA 30332", "(404) 894-2000">**
  is a tuple belonging to the CUSTOMER relation.
- A relation may be regarded as a ***set of tuples*** (rows).
- Columns in a table are also called attributes of the relation.

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FORMAL DEFINITIONS

- A **domain** has a logical definition: e.g., "India-PIN-Code" are the set of 6 digit Postal Index Numbers valid in India.
- A domain may have a data-type or a format defined for it. The USA_phone_numbers may have a format: (ddd)-ddd-dddd where each d is a decimal digit. E.g., Dates have various formats such as monthname, date, year or yyyy-mm-dd, or dd mm,yyyy etc.
- An attribute designates the **role** played by the domain. E.g., the domain Date may be used to define attributes "Invoice-date" and "Payment-date".

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FORMAL DEFINITIONS

- The relation is formed over the cartesian product of the sets; each set has values from a domain; that domain is used in a specific role which is conveyed by the attribute name.
- For example, attribute Cust-name is defined over the domain of strings of 25 characters. The role these strings play in the CUSTOMER relation is that of the name of customers.
- Formally,

  Given $R(A_1, A_2, ..., A_n)$

  $r(R) \subset dom(A_1) \times dom(A_2) \times ....X\ dom(A_n)$
- R: schema of the relation
- r of R: a specific "value" or population of R.
- R is also called the **intension** of a relation
- r is also called the **extension** of a relation

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FORMAL DEFINITIONS

- Let S1 = {0,1}
- Let S2 = {a,b,c}
- Let R $\subset$ S1 X S2
- Then for example: r(R) = {<0,a> , <0,b> , <1,c> }
  is one possible "state" or "population" or "extension" r of the relation R, defined over domains S1 and S2. It has three tuples.

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DEFINITION SUMMARY

Informal Terms		Formal Terms
Table		Relation
Column		Attribute/Domain
Row		Tuple
Values in a column		Domain
Table Definition		Schema of a Relation
Populated Table		Extension

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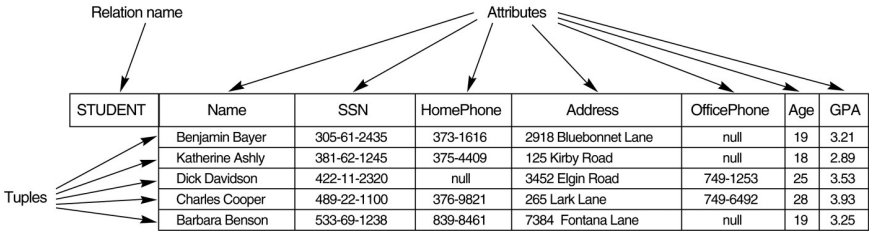
Example



STUDENT	Name	SSN	HomePhone	Address	OfficePhone	Age	GPA
	Benjamin Bayer	305-61-2435	373-1616	2918 Bluebonnet Lane	null	19	3.21
	Katherine Ashly	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
	Charles Cooper	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

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CHARACTERISTICS OF RELATIONS

STUDENT	Name	SSN	HomePhone	Address	OfficePhone	Age	GPA
	Dick Davidson	422-11-2320	null	3452 Elgin Road	749-1253	25	3.53
	Barbara Benson	533-69-1238	839-8461	7384 Fontana Lane	null	19	3.25
	Charles Cooper	489-22-1100	376-9821	265 Lark Lane	749-6492	28	3.93
	Katherine Ashly	381-62-1245	375-4409	125 Kirby Road	null	18	2.89
	Benjamin Bayer	305-61-2435	373-1616	2918 Bluebonnet Lane	null	19	3.21

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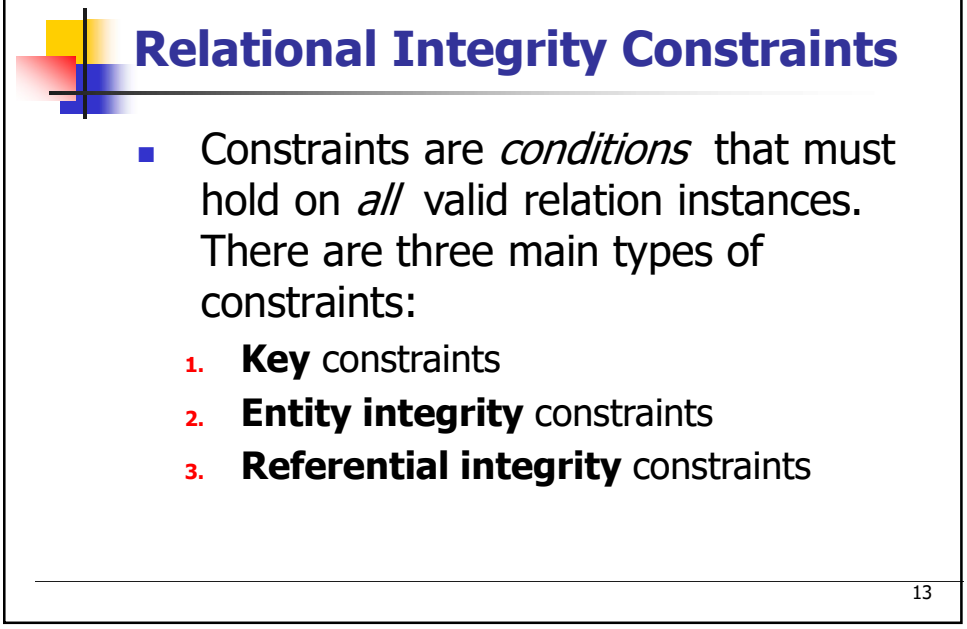

Relational Integrity Constraints

- Constraints are *conditions* that must hold on *all* valid relation instances. There are three main types of constraints:
  1. **Key** constraints
  2. **Entity integrity** constraints
  3. **Referential integrity** constraints

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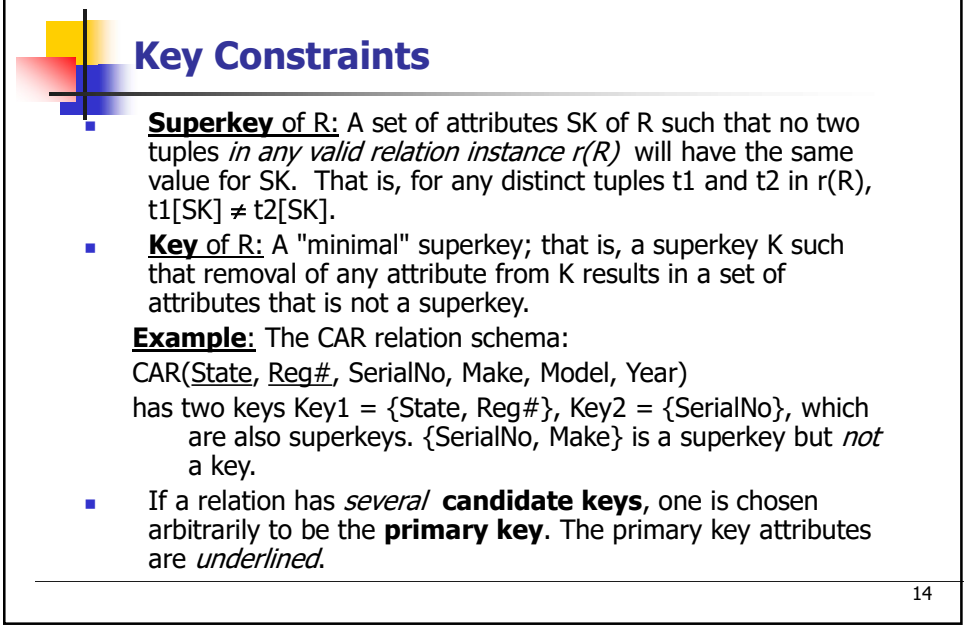

Key Constraints

- **Superkey** of R: A set of attributes SK of R such that no two tuples *in any valid relation instance r(R)* will have the same value for SK. That is, for any distinct tuples t1 and t2 in r(R), t1[SK] ≠ t2[SK].
- **Key** of R: A "minimal" superkey; that is, a superkey K such that removal of any attribute from K results in a set of attributes that is not a superkey.

Example: The CAR relation schema:

CAR(State, Reg#, SerialNo, Make, Model, Year)

has two keys Key1 = {State, Reg#}, Key2 = {SerialNo}, which are also superkeys. {SerialNo, Make} is a superkey but *not* a key.

- If a relation has *several* **candidate keys**, one is chosen arbitrarily to be the **primary key**. The primary key attributes are *underlined*.

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Key Constraints

Figure 7.4 The CAR relation with two candidate keys: LicenseNumber and EngineSerialNumber.

CAR	LicenseNumber	EngineSerialNumber	Make	Model	Year
	Texas ABC-739	A69352	Ford	Mustang	96
	Florida TVP-347	B43696	Oldsmobile	Cutlass	99
	New York MPO-22	X83554	Oldsmobile	Delta	95
	California 432-TFY	C43742	Mercedes	190-D	93
	California RSK-629	Y82935	Toyota	Camry	98
	Texas RSK-629	U028365	Jaguar	XJS	98

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Entity Integrity

- **Relational Database Schema**: A set S of relation schemas that belong to the same database. S is the *name* of the **database**.

$$S = \{R_1, R_2, ..., R_n\}$$

- **Entity Integrity**: The *primary key attributes* PK of each relation schema R in S cannot have null values in any tuple of r(R). This is because primary key values are used to *identify* the individual tuples.

$$t[PK] \neq \text{null for any tuple t in r(R)}$$

- Note: Other attributes of R may be similarly constrained to disallow null values, even though they are not members of the primary key.

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Referential Integrity

- A constraint involving *two* relations (the previous constraints involve a *single* relation).
- Used to specify a *relationship* among tuples in two relations: the **referencing relation** and the **referenced relation**.
- Tuples in the *referencing relation* R_1 have attributes FK (called **foreign key** attributes) that reference the primary key attributes PK of the *referenced relation* R_2. A tuple t_1 in R_1 is said to **reference** a tuple t_2 in R_2 if $t_1[FK] = t_2[PK]$.
- A referential integrity constraint can be displayed in a relational database schema as a directed arc from R_1.FK to R_2.

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Referential Integrity

- Informally
  - Referential Integrity constraint states that a tuple in one relation that refers to another relation must refer an existing relation in that tuple
  - Eg: The attribute DNO of EMPLOYEE gives the dept. no. for which each employee works
    - Hence its value in every EMPLOYEE tuple must match the DNUMBER value of some tuple in the DEPARTMENT relation

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Figure 5.5 Schema diagram for the COMPANY relational database schema; the primary keys are underlined.

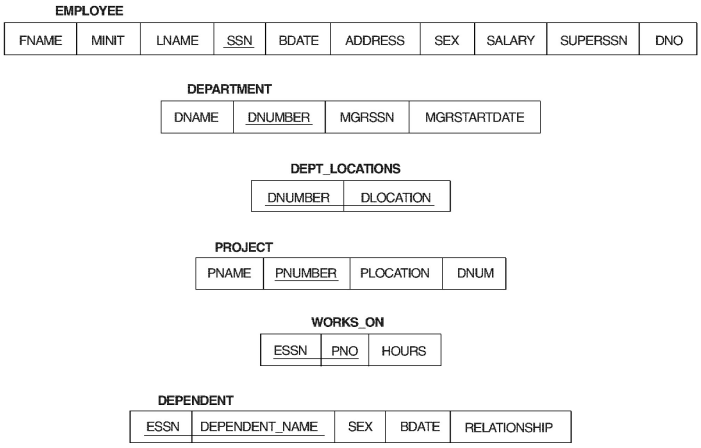
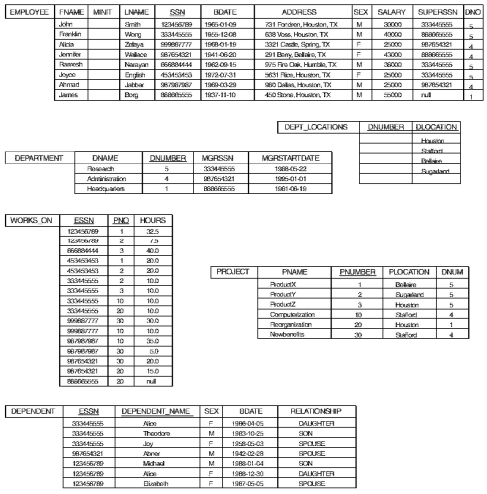


Figure 5.6 One possible relational database state corresponding to the COMPANY schema.



EMPLOYEE

FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO
John		Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin		Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia		Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer		Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh		Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce		English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad		Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James		Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	null	1

DEPT_LOCATIONS

DNUMBER	DLOCATION
	Houston
	Stafford
	Bellaire
	Sugarland

DEPARTMENT

DNAME	DNUMBER	MGRSSN	MGRSTARTDATE
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

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

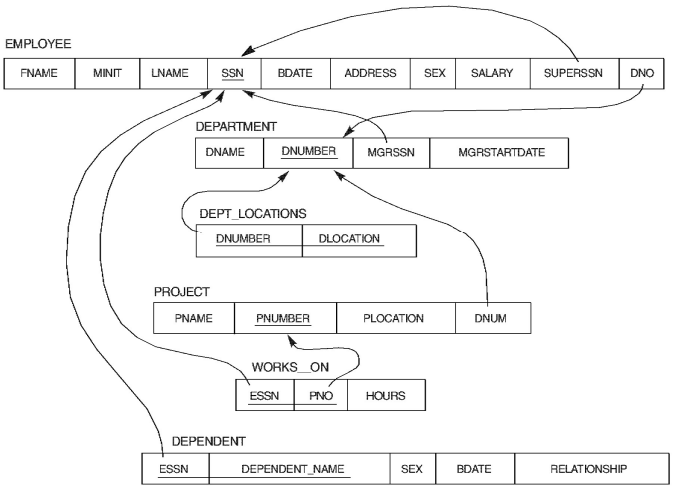
PROJECT

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 5.7 Referential integrity constraints displayed on the COMPANY relational database schema diagram.



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Update Operations on Relations

- INSERT a tuple.
- DELETE a tuple.
- MODIFY a tuple.

- Integrity constraints should not be violated by the update operations.
- Several update operations may have to be grouped together.
- Updates may *propagate* to cause other updates automatically. This may be necessary to maintain integrity constraints.

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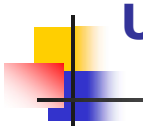

Update Operations on Relations

- In case of integrity violation, several actions can be taken:
  - Cancel the operation that causes the violation (REJECT option)
  - Perform the operation but inform the user of the violation
  - Trigger additional updates so the violation is corrected (CASCADE option, SET NULL option)
  - Execute a user-specified error-correction routine

Acknowledgement

Reference for this lecture is

- Ramez Elmasri and Shamkant B. Navathe, *Fundamentals of Database Systems,* Pearson Education.

The authors and the publishers are gratefully acknowledged.