Module 2

Chapter 1: The Relational Data Model

Introduction

The relational data model was first introduced by Ted Codd of IBM Research in 1970 in a classic paper (Codd 1970), and it attracted immediate attention due to its simplicity and mathematical foundation. The model uses the concept of a mathematical relation which looks somewhat like a table of values as its basic building block, and has its theoretical basis in set theory and first-orderpredicate logic.

The first commercial implementations of the relational model became available in the early 1980s, such as the SQL/DS system on the MVS operating system by IBM and the Oracle DBMS. Since then, the model has been implemented in a large number of commercial systems. Current popular relational DBMSs (RDBMSs) include DB2 and Informix Dynamic Server (from IBM), Oracle and Rdb (from Oracle), Sybase DBMS (from Sybase) and SQLServer and Access (from Microsoft). In addition, several open source systems, such as MySQL and PostgreSQL, are available.

1.1Relational Model Concepts

The relational model represents the database as a collection of relations. Informally, each relation resembles a table of values or, to some extent, a flat file of records. It is called a flat file because each record has a simple linear or flat structure.

When a relation is thought of as a table of values, each row in the table represents a collection of related data values. A row represents a fact that typically corresponds to a real-world entity or relationship. The table name and column names are used to help to interpret the meaning of the values in each row.

For example, in STUDENT relation because each row represents facts about a particular student entity. The column names Name, Student_number, Class, and Major specify how to interpret the data values in each row, based on the column each value is in. All values in a column are of the same data type.

In the formal relational model terminology, a row is called a tuple, a column header is called an attribute, and the table is called a relation. The data type describing the types of values that can appear in each column is represented by a domain of possible values.

1.1.1 Domains, Attributes, Tuples, and Relations

Domain

A domain D is a set of atomic values. By atomic we mean that each value in the domain is indivisible as far as the formal relational model is concerned. A common method of specifying a domain is to specify a data type from which the data values forming the domain are drawn. It is also useful to specify a name for the domain, to help in interpreting its values.

Some examples of domains follow:

- Usa_phone_numbers: The set of ten-digit phone numbers valid in the United States
- Social security_numbers: The set of valid nine-digit Social Security numbers.
- Names: The set of character strings that represent names of persons
- Employee_ages: Possible ages of employees in a company: each must be an integer value between 15 and 80

The preceding is called logical definitions of domains. A **data type** or **format** is also specified for each domain. For example, the data type for the domain Usa_phone_numbers can be declared as a character string of the form (ddd)ddddddd, where each d is a numeric (decimal) digit and the first three digits form a valid telephone area code. The data type for Employee_ages is an integer number between 15 and 80.

Attribute

An attribute A_i is the name of a role played by some domain D in the relation schema R. D iscalled the **domain** of A_i and is denoted by **dom**(A_i).

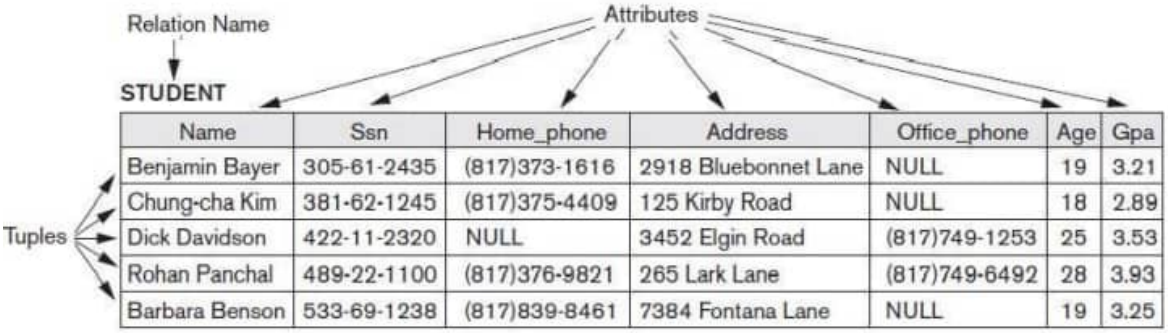
Tuple

Mapping from attributes to values drawn from the respective domains of those attributes. Tuples are intended to describe some entity (or relationship between entities) in the miniworld Example: a tuple for a PERSON entity might be

{ Name --> "smith", Gender --> Male, Age --> 25 }

Relation

A named set of tuples all of the same form i.e., having the same set of attributes.



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

Relation schema

A **relation schema** R, denoted by R(A_1, A_2, ...,A_n), is made up of a relation name R and a list of attributes A_1, A_2, ...,A_n. Each **attribute** A_i is the name of a role played by some domain D inthe relation schema R. D is called the **domain** of A_i and is denoted by **dom**(A_i). A relation schema is used to *describe* a relation; *R* is called the **name** of this relation.

The **degree (or arity)** of a relation is the number of attributes n of its relation schema. A relation of degree seven, which stores information about university students,would contain seven attributes describing each student. as follows:

STUDENT(Name, Ssn, Home_phone, Address, Office_phone, Age, Gpa)

Using the data type of each attribute, the definition is sometimes written as:

STUDENT(Name: string, Ssn: string, Home_phone: string, Address: string,
Office_phone: string, Age: integer, Gpa: real)

Domains for some of the attributes of the STUDENT relation:

dom(Name) = Names; dom(Ssn) =Social_security_numbers;
dom(HomePhone)=USA_phone_numbers,dom(Office_phone)= USA_phone_numbers,

Relation (or relation state)

A relation (or relation state) r of the relation schema by R(A_1, A_2, ...,A_n), also denoted by r(R), is a set of n-tuples r = {t_1, t_2, ..., t_m}. Each n-tuple t is an ordered list of n values t =<v_1, v_2, ..., v_n>, where each value v_i, $1 \leq i \leq n$, is an element of dom (A_i) or is a special NULL value. The i^{th} value in tuple t, which corresponds to the attribute A_i, is referred to as t[A_i] or t. A_i .

The terms **relation intension** for the schema R and **relation extension** for a relation state r(R)are also commonly used.

1.1.2 CHARACTERISTICS OF A RELATION

1. **Ordering of Tuples in a Relation**

   A relation is defined as a set of tuples. Mathematically, elements of a set have no order among them; hence, tuples in a relation do not have any particular order. Tuple ordering is not part of a relation definition because a relation attempts to represent facts at a logical or abstract level. Many tuple orders can be specified on the same relation.

2. **Ordering of Values within a Tuple and an Alternative Definition of a Relation**

   The order of attributes and their values is *not* that important as long as the correspondence between attributes and values is maintained. An alternative definition of a relation can begiven, making the ordering of values in a tuple unnecessary. In this definition A **relationschema** $R(A_1, A_2, ..., A_n)$, set of attributes and a **relation state r(R)** is a finite set of mappings $r = \{t_1, t_2, ..., t_m\}$, where each tuple ti is a **mapping** from R to D.

   According to this definition of tuple as a mapping, a **tuple** can be considered as a set of (<attribute>, <value>) pairs, where each pair gives the value of the mapping from an attribute A_i to a value vi from $dom(A_i)$ .The ordering of attributes is not important, because the attribute name appears with its value.

3. **Values and NULLs in the Tuples**

   Each value in a tuple is atomic. NULL values are used to represent the values of attributes that may be unknown or may not apply to a tuple. For example some STUDENT tuples have NULL for their office phones because they do not have an office .Another student has a NULL for home phone In general, we can have several meanings for NULL values, such as **value unknown**, **value** exists but is **not available**, or **attribute does not apply** to this tuple (also known as **value undefined**).

4. **Interpretation (Meaning) of a Relation**

   The relation schema can be interpreted as a declaration or a type of **assertion**. For example, the schema of the STUDENT relation of asserts that, in general, a student

entity has a Name, Ssn, Home_phone, Address, Office_phone, Age, and Gpa. Each tuple in the relation can then be interpreted as a particular instance of the assertion. For example, the first tuple asserts the fact that there is a STUDENT whose Name is Benjamin Bayer, Ssn is 305-61-2435, Age is 19, and so on. An alternative interpretation of a relation schema is as a **predicate**; in this case, the values in each tuple are interpreted as values that satisfy the predicate.

1.1.3 Relational Model Notation

- Relation schema R of degree n is denoted by by R(A1, A2, ...,An)
  Uppercase letters Q, R, S denote relation names
- Lowercase letters q, r, s denote relation statesLetters t,
  u, v denote tuples
- In general, the name of a relation schema such as STUDENT also indicates the current set of tuples in that relation
- An attribute A can be qualified with the relation name R to which it belongs by using the dot notation R->A for example, STUDENT.Name or STUDENT.Age.
- An *n*-tuple *t* in a relation *r*(*R*) is denoted by $t = <v1, v2, ..., vn>$, where v_i is the value corresponding to attribute A_i. The following notation refers to **component values** of tuples:
  Both $t[A_i]$ and $t.A_i$ (and sometimes $t[i]$) refer to the value v_i in *t* for attribute A_i.
- Both $t[A_u, A_w, ..., A_z]$ and $t.(A_u, A_w, ..., A_z)$, where $A_u, A_w, ..., A_z$ is a list of attributes from *R*, refer to the subtuple of values $<v_u, v_w, ..., v_z>$ from *t* corresponding to the attributes specifiedin the list.

1.2 Relational Model Constraints and Relational Database Schemas

Constraints are restrictions on the actual values in a database state. These constraints are derived from the rules in the mini world that the database represents. Constraints on databasescan generally be divided into three main categories:

1. Inherent model-based constraints or implicit constraints
   - Constraints that is inherent in the data model.
   - The characteristics of relations are the inherent constraints of the relational model and belong to the first category. For example, the constraint that a relation cannot have duplicate tuples is an inherent constraint.

2. Schema-based constraints or explicit constraints

- Constraints that can be directly expressed in schemas of the data model, typicallyby specifying them in the DDL.
- The schema-based constraints include domain constraints, key constraints, constraintson NULLs, entity integrity constraints, and referential integrity constraints.

3. Application-based or semantic constraints or business rules

- Constraints that cannot be directly expressed in the schemas of the data model, andhence must be expressed and enforced by the application programs.
- Examples of such constraints are the salary of an employee should not exceed the salary of the employee's supervisor and the maximum number of hours an employeecan work on all projects per week is 56.

1.2.1 Domain Constraints

Domain Constraints specify that within each tuple, the value of each attribute A must be an atomic value from the domain dom(A). The data types associated with domains typically include standard numeric data types for integers (such as short integer, integer, and long integer) and real numbers (float and double precision float). Characters, Booleans, fixed-length strings, and variable-length strings are also available, date, time, timestamp, and money, or other special data types.

1.2.2 Key Constraints and Constraints on NULL Values

All tuples in a relation must also be distinct. This means that no two tuples can have the same combination of values for all their attributes. There are other subsets of attributes of a relation schema R with the property that no two tuples in any relation state r of R should have the same combination of values for these attributes.

Suppose that we denote one such subset of attributes by SK; then for any two distinct tuples t1 and t2 in a relation state r of R, we have the constraint that:

$t1[SK] \neq t2[SK]$. Such set of attributes SK is called a superkey of the relation schema R

SUPERKEY

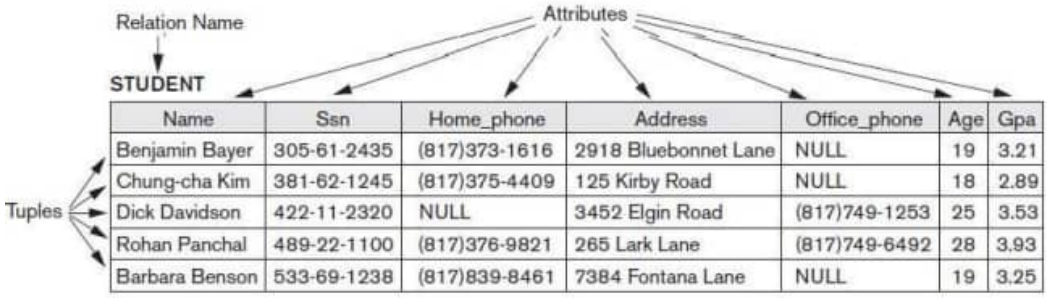
A superkey SK specifies a uniqueness constraint that no two distinct tuples in any state r of R can have the same value for SK. Every relation has at least one default superkey the set of all its attributes.

Key

A key K of a relation schema R is a superkey of R with the additional property that removing any attribute A from K leaves a set of attributes K that is not a superkey of R anymore. Hence, a key satisfies two properties:

1. Two distinct tuples in any state of the relation cannot have identical values for (all) the attributes in the key. This first property also applies to a superkey.
2. It is a minimal superkey that is, a superkey from which we cannot remove any attributes and still have the uniqueness constraint in condition 1 hold. This property is not required by a superkey.

Example: Consider the STUDENT relation



Name	Ssn	Home_phone	Address	Office_phone	Age	Gpa
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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
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- The attribute set {Ssn} is a key of STUDENT because no two student tuples can have the same value for Ssn
- Any set of attributes that includes Ssn—for example, {Ssn, Name, Age}—is a superkey
- The superkey {Ssn, Name, Age} is not a key of STUDENT because removing Name or Age or both from the set still leaves us with a superkey

In general, any superkey formed from a single attribute is also a key. A key with multiple attributes must require *all* its attributes together to have the uniqueness property.

Candidate key

A relation schema may have more than one key. In this case, each of the keys is called a **candidate key.** For example, the CAR relation has two candidate keys: License_number and Engine_serial_number

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

Primary key

It is common to designate one of the candidate keys as the **primary key** of the relation. This is the candidate key whose values are used to identify tuples in the relation. We use the convention that the attributes that form the primary key of a relation schema are underlined. Other candidate keys are designated as **unique keys** and are not underlined

Another constraint on attributes specifies whether NULL values are or are not permitted. For example, if every STUDENT tuple must have a valid, non-NULL value for the Name attribute, thenName of STUDENT is constrained to be NOT NULL.

1.2.3 Relational Databases and Relational Database Schemas

A Relational database schema *S is a* set of relation schemas $S = \{R1, R2, ..., Rm\}$ and a s etof integrity constraints IC.

Example of relational database schema:

COMPANY = {EMPLOYEE, DEPARTMENT, DEPT_LOCATIONS,
PROJECT,WORKS_ON, DEPENDENT}

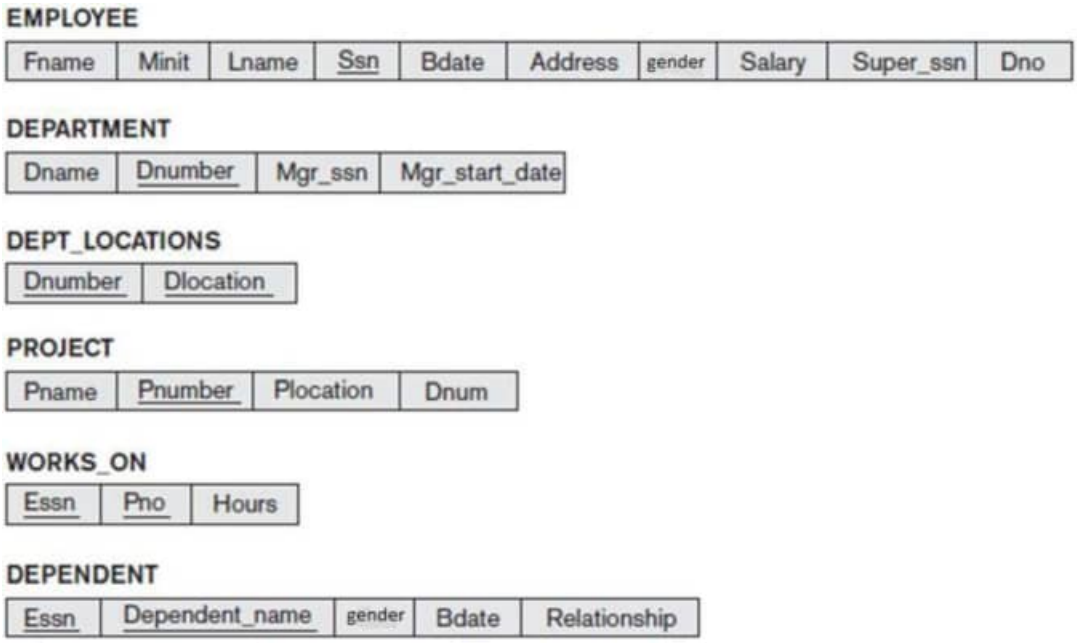


Figure1.2.3 (a): Schema diagram for the COMPANY relational database schema.

The underlined attributes represent primary keys

A Relational database state is a set of relation states $DB = \{r1, r2, ..., rm\}$.Each ri is a state of R and such that the r_i relation states satisfy integrity constraints specified in IC.

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	gender	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

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	gender	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 1.2.3(b): One possible database state for the COMPANY relational database schema.

A database state that does not obey all the integrity constraints is called Invalid state and a state that satisfies all the constraints in the defined set of integrity constraints IC is called a valid state

Attributes that represent the same real-world concept may or may not have identical names in different relations. For example, the Dnumber attribute in both DEPARTMENT and DEPT_LOCATIONS stands for the same real-world concept the number given to a department. That same concept is called Dno in EMPLOYEE and Dnum in PROJECT.

Alternatively, attributes that represent different concepts may have the same name in different relations. For example, we could have used the attribute name Name for both Pname of PROJECT and Dname of DEPARTMENT; in this case, we would have two attributes that share the same name but represent different realworld concepts project names and department names.

1.2.4 Integrity, Referential Integrity, and Foreign Keys Entity

integrity constraint

The entity integrity constraint states that no primary key value can be NULL. This is because the primary key value is used to identify individual tuples in a relation. Having NULL values for the primary key implies that we cannot identify some tuples. For example, if two or more tuples had NULL for their primary keys, we may not be able to distinguish them if we try to reference them from other relations.

Key constraints and entity integrity constraints are specified on individual relations.

Referential integrity constraint

The referential integrity constraint is specified between two relations and is used to maintain the consistency among tuples in the two relations. Informally, the referential integrity constraint states that a tuple in one relation that refers to another relation must refer to an existing tuple in that relation.

For example COMPANY database, the attribute Dno of EMPLOYEE gives the department numberfor which each employee works; hence, its value in every EMPLOYEE tuple must match the Dnumber value of some tuple in the DEPARTMENT relation.

To define referential integrity more formally, first we define the concept of a *foreign key*. The conditions for a foreign key, given below, specify a referential integrity constraint between the two relation schemas $R1$ and $R2$.

A set of attributes FK in relation schema $R1$ is a **foreign key** of $R1$ that **references** relation $R2$ if it satisfies the following rules:

1. Attributes in FK have the same domain(s) as the primary key attributes PK of $R2$; the attributes FK are said to **reference** or **refer to** the relation $R2$.
2. A value of FK in a tuple $t1$ of the current state $r1(R1)$ either occurs as a value of PK for some tuple $t2$ in the current state $r2(R2)$ *or is NULL*.

In the former case, we have $t1[FK] = t2[PK]$, and we say that the tuple $t1$ **references** or **refers to** the tuple $t2$.

In this definition, R1 is called the **referencing relation** and R2 is the **referenced relation**. If these two conditions hold, a **referential integrity constraint** from R1 to R2 is said to hold.

1.2.5 OTHER TYPES OF CONSTRAINTS

Semantic Integrity Constraints

Semantic integrity constraints can be specified and enforced within the application programs that update the database, or by using a general-purpose constraint specification language**.** Examples of such constraints are the salary of an employee should not exceed the salary of the employee's supervisor and the maximum number of hours an employee can work on all projects per week is 56. Mechanisms called **triggers** and **assertions** can be used. In SQL, CREATE ASSERTION and CREATE TRIGGER statements can be used for this purpose.

Functional dependency constraint

Functional dependency constraint establishes a functional relationship among two sets of attributes X and Y. This constraint specifies that the value of X determines a unique value of Y in all states of a relation; it is denoted as a functional dependency X->Y. We use functional dependencies and other types of dependencies as tools to analyze the quality of relations to improve their quality.

State constraints (static constraints)

Define the constraints that a valid state of the database must satisfy

Transition constraints (dynamic constraints)

Define to deal with state changes in the database

1.3 Update Operations, Transactions, and Dealing with Constraint Violations

The operations of the relational model can be categorized into **retrievals** and **updates**

There are three basic operations that can change the states of relations in the database:

1. Insert - used to insert one or more new tuples in a relation
2. Delete- used to delete tuples
3. Update (or Modify)- used to change the values of some attributes in existing tuples

Whenever these operations are applied, the integrity constraints specified on the relational databaseschema should not be violated.

1.3.1 The Insert Operation

The Insert operation provides a list of attribute values for a new tuple *t* that is to be inserted into relation *R*. Insert can violate any of the four types of constraints

1. **Domain constraints :** if an attribute value is given that does not appear in the corresponding domain or is not of the appropriate data type
2. **Key constraints :** if a key value in the new tuple *t* already exists in another tuple in the relation *r*(*R*)
3. **Entity integrity:** if any part of the primary key of the new tuple *t* is NULL
4. **Referential integrity :** if the value of any foreign key in *t* refers to a tuple that does not exist in the referenced relation

Examples:

1. Operation:

Insert <'cecilia','F','KOLONSKY',NULL,1960-04-05','6357 windy lane,katy,tx'>

Result: This insertion violates the entity integrity constraint (NULL for the primary keySsn), so it is rejected

1. Operation:

Insert <'Alicia', 'J', 'Zelaya', '999887777', '1960-04-05', '6357 Windy Lane, Katy, TX', F, 28000, '987654321', 4>

Result: This insertion violates the key constraint because another tuple with the same Ssn value already exists in the EMPLOYEE relation, and so it is rejected.

2.Operation:

Insert <'cecilia', 'F','kolonsky', '677678989','1960-04-05','6357 windy lane,katy,tx',F,28000,'987654321,7>

Result: This insertion violates the referential integrity constraint specified on Dno in EMPLOYEE because no corresponding referenced tuple exists in DEPARTMENT with Dnumber = 7.

3. Operation:

Insert <'cecilia', 'F', '677678989','1960-04-05','6357 windy lane,katy,tx',F,28000,NULL,4>

Result: This insertion satisfies all constraints, so it is acceptable.

If an insertion violates one or more constraints, the default option is to reject the insertion. It would be useful if the DBMS could provide a reason to the user as to why the insertion was rejected. Another option is to an attempt to correct the reason for rejecting the insertion.

1.3.2 The Delete Operation

The Delete operation can violate only referential integrity. This occurs if the tuple being deleted is referenced by foreign keys from other tuples in the database. To specify deletion, a condition on the attributes of the relation selects the tuple (or tuples) to be deleted.

Examples:

1. Operation:

   Delete the WORKS_ON tuple with Essn='999887777' and Pno=10.

   Result: This deletion is acceptable and deletes exactly one tuple.

2. Operation:
   Delete the EMPLOYEE tuple with Ssn='999887777';

   Result: This deletion is not acceptable, because there are tuples in WORKS_ON that referto this tuple. Hence, if the tuple in EMPLOYEE is deleted, referential integrity violations will result.

3. Operation:
   Delete the EMPLOYEE tuple with Ssn='33344555';

   Result: This deletion will result in even worse referential integrity violations, because thetuple involved is referenced by tuples from the EMPLOYEE, DEPARTMENT, WORKS_ON, and DEPENDENT relations.

Several options are available if a deletion operation causes a violation

1. restrict - is to reject the deletion
2. cascade, is to attempt to cascade (or propagate) the deletion by deleting tuples that referencethe tuple that is being deleted
3. Set null or set default - is to modify the referencing attribute values that cause the violation; each such value is either set to NULL or changed to reference another default valid tuple.

1.3.3 The Update Operation

The Update (or Modify) operation is used to change the values of one or more attributes in a tuple (or tuples) of some relation *R*. It is necessary to specify a condition on the attributes of the relationto select the tuple (or tuples) to be modified.

Examples:

1. Operation:

   Update the salary of the EMPLOYEE tuple with Ssn = '999887777' to 28000;

Result: Acceptable.

2. Operation:

   Update the Dno of the EMPLOYEE tuple with Ssn='999887777' to 7.

   Result: Unacceptable, because it violates referential integrity.

3. Operation:

   Update the Ssn of the EMPLOYEE tuple with Ssn='999887777' to '987654321'.

Result: Unacceptable, because it violates primary key constraint by repeating a value that already exists as a primary key in another tuple; it violates referential integrity constraints because there are other relations that refer to the existing value of Ssn

Updating an attribute that is neither part of a primary key nor of a foreign key usually causes no problems; the DBMS need only check to confirm that the new value is of the correct data type and domain.

1.3.4 The Transaction Concept

A **transaction** is an executing program that includes some database operations, such as reading fromthe database, or applying insertions, deletions, or updates to the database. At the end of the transaction, it must leave the database in a valid or consistent state that satisfies all the constraints specified on the database schema A single transaction may involve any number of retrieval operations and any number of update operations. These retrievals and updates will together form anatomic unit of work against the database. For example, a transaction to apply a bank withdrawal will typically read the user account record, check if there is a sufficient balance, and then update the record by the withdrawal amount.

Chapter 2: RELATIONAL ALGEBRA

2.1Unary and Binary relational operations SELECT and PROJECT

2.1.1 The SELECT Operation

- The SELECT operation is used to choose a subset of the tuples from a relation that satisfies a selection condition.
- It restricts the tuples in a relation to only those tuples that satisfy the condition.
- It can also be visualized as a horizontal partition of the relation into two sets of tuples—those tuples that satisfy the condition and are selected, and those tuples that do not satisfy the condition and are discarded.
- For example, to select the EMPLOYEE tuples whose department is 4, or those whose salary is greater than $30,000

$$\sigma_{Dno=4}(EMPLOYEE)$$
$$\sigma_{Salary>30000}(EMPLOYEE)$$

In general, the SELECT operation is denoted by

σ<selection condition>(R)

where the symbol σ (sigma) is used to denote the SELECT operator and the selection condition is a Boolean expression (condition) specified on the attributes of relation R.

- The Boolean expression specified in is made up of a number of clauses of the form :

  <attribute name><comparison op><constant value>

  Or

  <attribute name><comparison op><attribute name>

- Clauses can be connected by the standard Boolean operators and, or, and not to form a general selection condition.
- For example, to select the tuples for all employees who either work in department 4 and make over

$25,000 per year, or work in department 5 and make over $30,000:

$$\sigma_{(Dno=4 \text{ AND } Salary>25000) \text{ OR } (Dno=5 \text{ AND } Salary>30000)}(EMPLOYEE)$$

- The Boolean conditions AND, OR, and NOT have their normal interpretation, as follows:
  - (cond1 AND cond2) is TRUE if both (cond1) and (cond2) are TRUE; otherwise,it is FALSE.
  - (cond1 OR cond2) is TRUE if either (cond1) or (cond2) or both are TRUE; otherwise, it is FALSE.
  - (NOT cond) is TRUE if cond is FALSE; otherwise, it is FALSE.

- The SELECT operator is unary; that is, it is applied to a single relation. Hence, selection conditions cannot involve more than one tuple.
- The degree of the relation resulting from a SELECT operation—its number of attributes—is the same as the degree of R.
- The SELECT operation is commutative; that is,

$$\sigma\ (cond1)(\sigma(cond2)(R)) = \sigma(cond2)(\sigma(cond1)(R))$$

2.1.2 The PROJECT Operation

- The PROJECT operation selects certain columns from the table and discards the other columns.
- The result of the PROJECT operation can be visualized as a vertical partition of the relation into two relations: one has the needed columns (attributes) and contains the result of the operation, and the other contains the discarded columns.
- For example, to list each employee's first and last name and salary, we can use the PROJECT operation as follows:

$$\pi \text{Lname, Fname, Salary}(\text{EMPLOYEE})$$

$$\pi <\text{attribute list}>(R)$$

- The general form of the PROJECT operation is where (pi) is the symbol used to represent the PROJECT operation, and is the desired sub list of attributes from the attributes of relation R.

- The result of the PROJECT operation has only the attributes specified in the same order as they appear in the list. Hence, its degree is equal to the number of attributes in <attribute list>.
- The PROJECT operation removes any duplicate tuples, so the result of the PROJECT operation is a set of distinct tuples, and hence a valid relation. This is known as duplicate elimination.

2.1.3 Sequences of Operations and the RENAME Operation

- The relations shown above depict operation results do not have any names.
- Either we can write the operations as a single relational algebra expression by nesting the operations, or we can apply one operation at a time and create intermediate result relations.
- In the latter case, we must give names to the relations that hold the intermediate results.
- For example, to retrieve the first name, last name, and salary of all employees who work in department number 5, applies a SELECT and a PROJECT operation.

$$\pi_{Fname, Lname, Salary}(\sigma_{Dno=5}(EMPLOYEE))$$

- Alternatively, we can explicitly show the sequence of operations, giving a name to

$$DEP5\_EMPS \leftarrow \sigma_{Dno=5}(EMPLOYEE)$$
$$RESULT \leftarrow \pi_{Fname, Lname, Salary}(DEP5\_EMPS)$$

each intermediate relation, and using the assignment operation, denoted by ← (left arrow), as follows:

- It is sometimes simpler to break down a complex sequence of operations by specifying intermediate result relations than to write a single relational algebra expression.
- We can also use this technique to rename the attributes in the intermediate and result relations.
- To rename the attributes in a relation, we simply list the new attribute names in parentheses, as in the following example:

TEMP ← σDno=5(EMPLOYEE)
R(First_name, Last_name, Salary) ← πFname, Lname, Salary(TEMP)

- The formal RENAME operation—which can rename either the relation name or the attribute names, or both—as a unary operator.
- The general RENAME operation when applied to a relation R of degree n is denoted by any of the following three forms:

  ρS(B1, B2, ... , Bn)(R) or ρS(R) or ρ(B1, B2, ... , Bn)(R)
- where the symbol ρ (rho) is used to denote the RENAME operator, S is the new relation name, and B1, B2, … , Bn are the new attribute names.
- The first expression renames both the relation and its attributes, the second renames the relation only, and the third renames the attributes only.

2.2 Relational Algebra Operations from Set Theory

2.2.1 The UNION, INTERSECTION, and MINUS Operations

- UNION: The result of this operation, denoted by R ∪ S, is a relation that includes all tuples that are either in R or in S or in both R and S. Duplicate tuples are eliminated.

- INTERSECTION: The result of this operation, denoted by R ∩ S, is a relation that includes all tuples that are in both R and S.

- SET DIFFERENCE (or MINUS): The result of this operation, denoted by R – S, is a relation that includes all tuples that are in R but not in S.

- These are binary operations; that is, each is applied to two sets (of tuples).
- When these operations are adapted to relational databases, the two relations on which any of these three operations are applied must have the same type of tuples; this condition has been called union compatibility or type compatibility.
- Two relations R(A1, A2, … , An) and S(B1, B2, … , Bn) are said to be union compatible (or type compatible) if they have the same degree n and if dom(Ai) = dom(Bi) for $1 \leq i \leq n$. This means that the two relations have the same number of attributes and each corresponding pair of attributes has the same domain.
- For example, to retrieve the Social Security numbers of all employees who either

work in department 5 or directly supervise an employee who works in department 5,

```
DEP5_EMPS ← σDno=5(EMPLOYEE)
RESULT1 ← πSsn(DEP5_EMPS)
RESULT2(Ssn) ← πSuper_ssn(DEP5_EMPS)
RESULT ← RESULT1 ∪ RESULT2
```

- Both UNION and INTERSECTION are commutative operations; that is,

$$R \cup S = S \cup R \text{ and } R \cap S = S \cap R$$

- Both UNION and INTERSECTION can be treated as n-ary operations applicable to any number of relations because both are also associative operations; that is,

$$R \cup (S \cup T) = (R \cup S) \cup T \text{ and } (R \cap S) \cap T = R \cap (S \cap T)$$

- The MINUS operation is not commutative; that is, in general, $R - S \neq S - R$
- The INTERSECTION can be expressed in terms of union and set difference as follows:

$$R \cap S = ((R \cup S) - (R - S)) - (S - R)$$

2.3 Additional Relational Operations (aggregate, grouping, etc.)

2.3.1 Generalized Projection

- The generalized projection operation extends the projection operation by allowing functions of attributes to be included in the projection list.
- The generalized form can be expressed as:

  $\pi F1, F2, ..., Fn (R)$

  where F1, F2, … , Fn are functions over the attributes in relation R and may involve arithmetic operations and constant values.
- This operation is helpful when developing reports where computed values have to be produced in the columns of a query result.
- Example: EMPLOYEE (Ssn, Salary, Deduction, Years_service) A report may be required to show

Net Salary = Salary – Deduction, Bonus = 2000 * Years_service, and Tax = 0.25 * Salary.

Then a generalized projection combined with renaming may be used as follows:

REPORT ← ρ(Ssn, Net_salary, Bonus, Tax)(πSsn, Salary – Deduction, 2000 * Years_service, 0.25 * Salary(EMPLOYEE))1

2.3.2 Aggregate Functions and Grouping

- Mathematical aggregate functions on collections of values from the database. Examples of such functions include retrieving the average or total salary of all employees or the total number of employee tuples.
- Common functions applied to collections of numeric values include SUM, AVERAGE, MAXIMUM, and MINIMUM.

  The COUNT function is used for counting tuples or values.
- AGGREGATE FUNCTION operation defined, using the symbol ℑ , to specify these types of requests as follows:

  <grouping attribute>ℑ<function list> (R)

  Where<grouping attribute> is a list of attributes of the relation specified in R, and <function list>is a list of (<function><attribute>) pairs.
- In each such pair, is one of the allowed functions—such as SUM, AVERAGE, MAXIMUM, MINIMUM, COUNT—and is an attribute of the relation specified by R.
- The resulting relation has the grouping attributes plus one attribute for each element in the function list.
- For example, to retrieve each department number, the number of employees in the department, and their average salary, while renaming the resulting attributes as indicated below, we write:

  ρR(Dno, No_of_employees, Average_sal) (Dno ℑ COUNT Ssn, AVERAGE Salary (EMPLOYEE))
- If we do not want to rename the attributes then the above query we can write it as, Dno ℑ COUNT Ssn, AVERAGE Salary(EMPLOYEE)

Note: If no grouping attributes are specified, the functions are applied to all the tuples in the relation, so the resulting relation has a single tuple only.

2.4 Join in relational Algebra

Join is a combination of a Cartesian product followed by a selection process. A Join operation pairs two tuples from different relations, if and only if a given join condition is satisfied

Various forms of join operation are:

- Inner Joins:
  - Theta join
  - EQUI join
  - Natural join
- Outer join:
  - Left Outer Join
  - Right Outer Join
  - Full Outer Join

2.4.1 Inner Join:

In an inner join, only those tuples that satisfy the matching criteria are included, while the rest are excluded.

Theta join(θ)

- The general case of JOIN operation is called a Theta join.
- It is denoted by symbol θ.
- Also Known as Conditional Join
- Used when you want to join two or more relation based on some conditions

Example

$P \bowtie_\theta Q$

Customer

Cid	Cname	Age
101	Ajay	20
102	Vijay	19
103	Sita	21

Order

Oid	Oname
101	Pizza
101	Noodles
103	Burger

Customer $\bowtie_{Customer.cid>Order.oid}$ Order

Cid	Cname	Age	Oid	Oname
102	Vijay	19	101	Pizza
102	Vijay	19	101	Noodles
103	Sita	21	101	Pizza
103	Sita	21	101	Noodles

Equi join

- Equijoin is a special case of conditional join
- When a theta join uses only equivalence condition, it becomes a equijoin.
- As values of two attributes will be equal in result of equijoin, only one attribute will be appeared in result.

Example

P ⋈ Q

Customer

Cid	Cname	Age
101	Ajay	20
102	Vijay	19
103	Sita	21

Order

Oid	Oname
101	Pizza
101	Noodles
103	Burger

Customer $\bowtie_{Customer.cid=Order.oid}$ Order

Cid	Cname	Age	Oname
101	Ajay	20	Pizza
101	Ajay	20	Noodles
103	Sita	21	Burger

$\Pi_{customer.cid,customer,cname,austomer.age,order.oname}(\sigma_{customer.cid=order.oid}(customer \times order))$

Natural join

- Natural join can only be performed if there is a common attribute (column) between the relations.
- The name and type (domain) of the attribute must be same
- Natural join does not use any comparison operator.
- It does not concatenate the way a Cartesian product does.
- Natural Join will also return the similar attributes only once as their value will be same in resulting relation.
- It is a special case of equijoin in which equality condition hold on all attributes which have same name in relations R and S.

Customer

Cid	Cname	Age
101	Ajay	20
102	Vijay	19
103	Sita	21
104	Gita	22

Order

Cid	Oname	Cost
101	Pizza	500
103	Noodles	300
108	Burger	99

Customer ⋈ Order

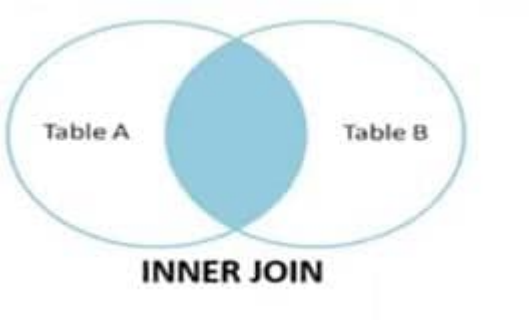
Cid	Cname	Age	Oname	Cost
101	Ajay	20	Pizza	500
103	Sita	21	Noodles	300

Drawback of Natural Join

- Natural join can only be performed if there is a common attribute (column) between the relations.
- It may lead to data loss, if attributes to be match have different names, or some values are present in both the tables.

Points to Remember

- The INNER JOIN keyword selects all rows from both the tables as long as the condition satisfies.
- It will create the result-set by combining all rows from both the tables where the condition satisfies i.e value of the common field will be same.



2.4.2 SQL Joins

A JOIN clause is used to combine rows from two or more tables, based on a related column between them.

Let's look at a selection from the "Orders" table:

OrderID	CustomerID	OrderDate
10308	2	1996-09-18
10309	37	1996-09-19
10310	77	1996-09-20

Then, look at a selection from the "Customers" table:

CustomerID	CustomerName	ContactName	Country
1	Alfreds Futterkiste	Maria Anders	Germany
2	Ana Trujillo Emparedados y helados	Ana Trujillo	Mexico
3	Antonio Moreno Taquería	Antonio Moreno	Mexico

Notice that the "CustomerID" column in the "Orders" table refers to the "CustomerID" in the "Customers" table. The relationship between the two tables above is the "CustomerID" column.

Then, we can create the following SQL statement (that contains an INNER JOIN), that selects records that have matching values in both tables:

Example

```
SELECT Orders.OrderID,Customers.CustomerName,Orders.OrderDate
FROM Orders
INNER JOIN Customers ON Orders.CustomerID=Customers.CustomerID;
```

OrderID	CustomerName	OrderDate
10308	Ana Trujillo Emparedados y helados	9/18/1996

Different Types of SQL JOINs

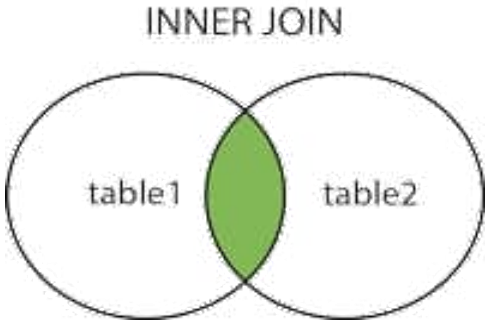
Here are the different types of the JOINs in SQL:

- **(INNER) JOIN**: Returns records that have matching values in both tables
- **LEFT (OUTER) JOIN**: Returns all records from the left table, and the matched records from the right table
- **RIGHT (OUTER) JOIN**: Returns all records from the right table, and the matched records from the left table
- **FULL (OUTER) JOIN**: Returns all records when there is a match in either left or right table

INNER JOIN Syntax

SQL INNER JOIN Keyword.The INNER JOIN keyword selects records that have matching values in both tables.

```
SELECT column_name(s)
FROM table1
INNER JOIN table2
ON table1.column_name = table2.column_name;
```

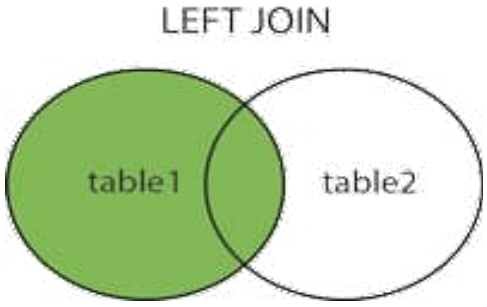


SQL LEFT JOIN Keyword

The LEFT JOIN keyword returns all records from the left table (table1), and the matched records from the right table (table2). The result is NULL from the right side, if there is no match.

LEFT JOIN Syntax

```
SELECT column_name(s)
FROM table1
LEFT JOIN table2
ON table1.column_name = table2.column_name;
```



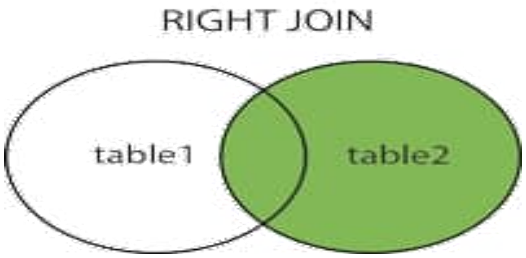
SQL RIGHT JOIN Keyword

The RIGHT JOIN keyword returns all records from the right table (table2), and the matched records from the left table (table1). The result is NULL from the left side, when there is no match.

RIGHT JOIN Syntax

```
SELECT column_name(s)
FROM table1
RIGHT JOIN table2
ON table1.column_name = table2.column_name;
```

Note: In some databases RIGHT JOIN is called RIGHT OUTER JOIN.



SQL FULL OUTER JOIN Keyword

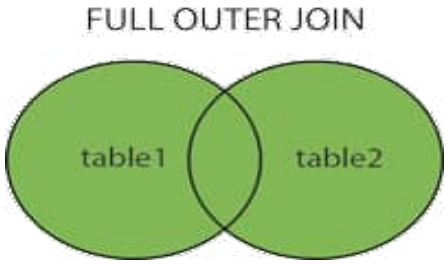
The FULL OUTER JOIN keyword returns all records when there is a match in left (table1) or right (table2) table records.

Note: FULL OUTER JOIN can potentially return very large result-sets!

Tip: FULL OUTER JOIN and FULL JOIN are the same.

FULL OUTER JOIN Syntax

```
SELECT column_name(s)
FROM table1
FULL OUTER JOIN table2
ON table1.column_name = table2.column_nameWHERE condition;
```



2.5 Relational Database Design Using ER-to-Relational Mapping

There are seven steps in this process

1. Convert all strong entity sets in relation
2. Mapping of weak entity types
3. Mapping of 1:1 relationship type
4. Mapping of 1:N relationship type
5. Mapping of M:N relationship type
6. Mapping multivalued attributes
7. Mapping of N-array relationship

Step 1 − Conversion of strong entities

- For each strong entity create a separate table with the same name.
- Includes all attributes, if there is any composite attribute divided into simple attributes and has to be included.
- Ignore multivalued attributes at this stage.
- Select the primary key for the table.

EMPLOYEE

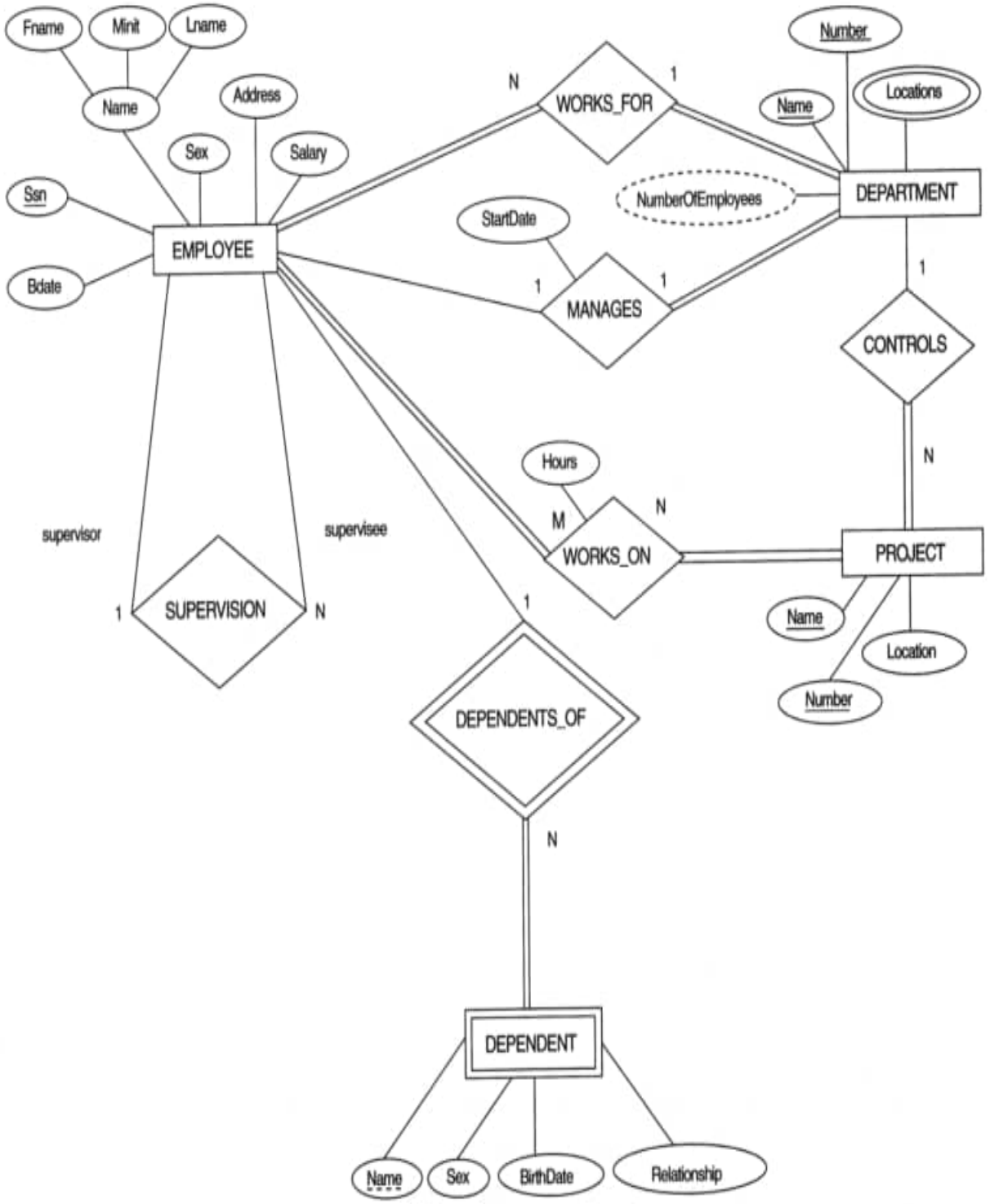
SSN	Fname	Mname	Lname	BDate	Address	Sex	Salary

DEPARTMENT

Dnumber	Dname

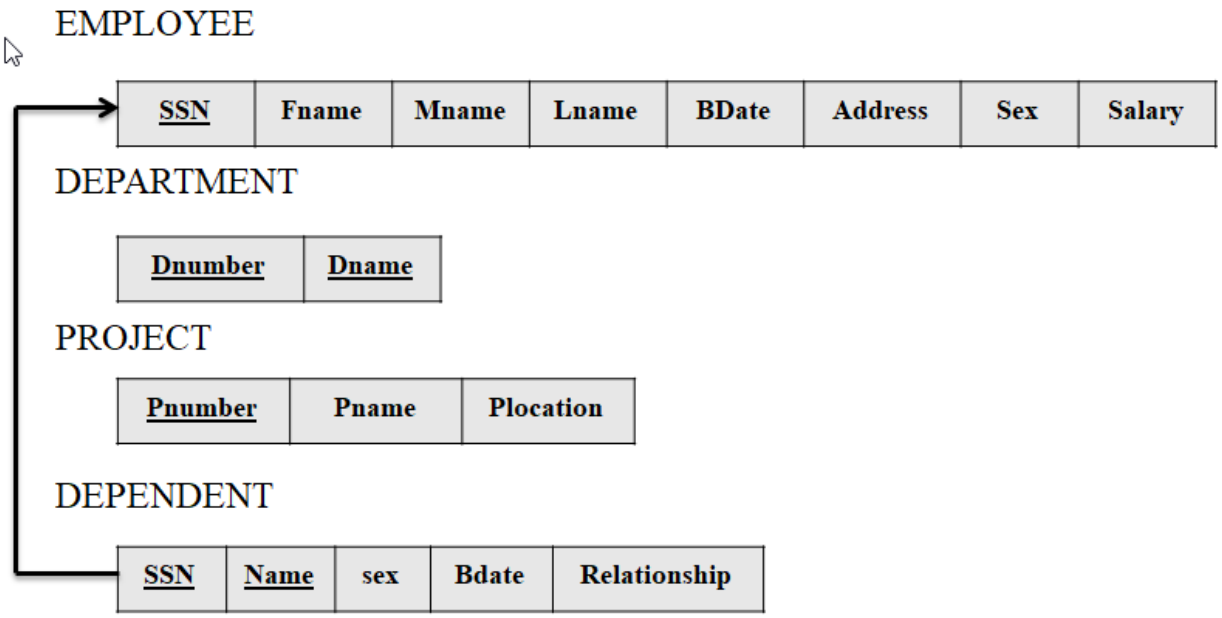
PROJECT

Pnumber	Pname	Plocation


Fname
Minit
Lname
Name
Address
Sex
Salary
Ssn
Bdate
EMPLOYEE
N
WORKS_FOR
1
Number
Name
Locations
DEPARTMENT
NumberOfEmployees
StartDate
1
MANAGES
1
1
CONTROLS
N
Hours
M
N
WORKS_ON
PROJECT
Name
Location
Number
supervisor
supervisee
1
SUPERVISION
N
1
DEPENDENTS_OF
N
DEPENDENT
Name
Sex
BirthDate
Relationship

Step 2 − Conversion of weak entity

- For each weak entity create a separate table with the same name.
- Include all attributes.
- Include the Primary key of a strong entity as foreign key is the weak entity.
- Declare the combination of foreign key and decimator attribute as Primary key from the weak entity.



Step 3 − Conversion of one-to-one relationship

There are 3 methods

Method 1: Foreign key approach

Let R and S be two entity sets

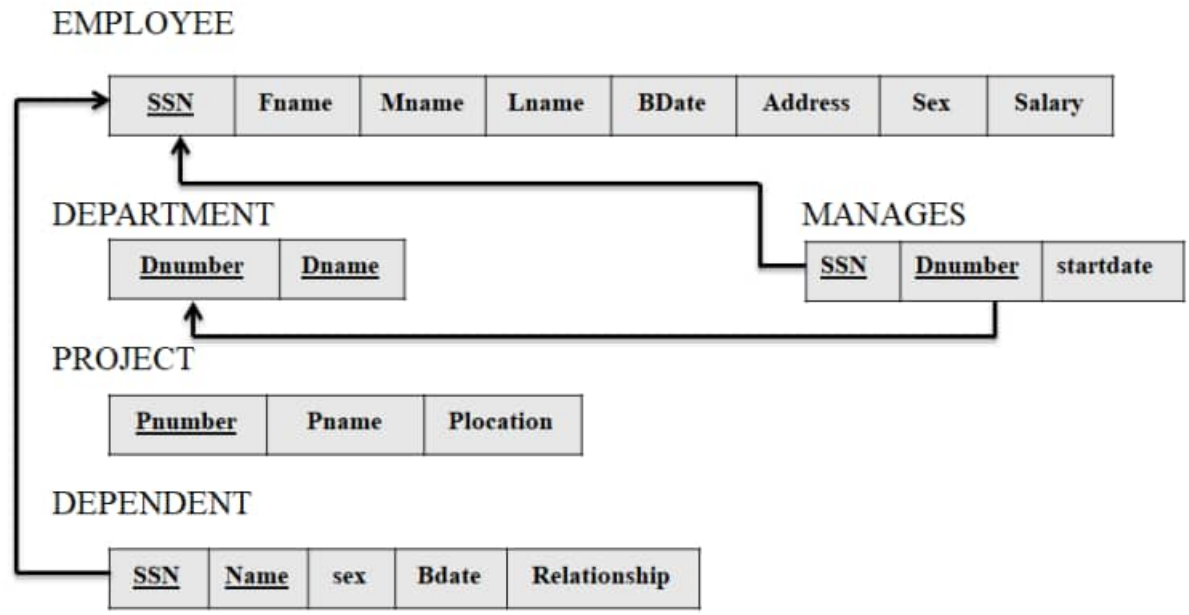
- Identify the entity set with total participation (let's say S entity is having the total participation).
- Add primary key of R to S.

Method 2: Merged relation approach

- If both the entity sets are having total participation then they can be merged into single relation.

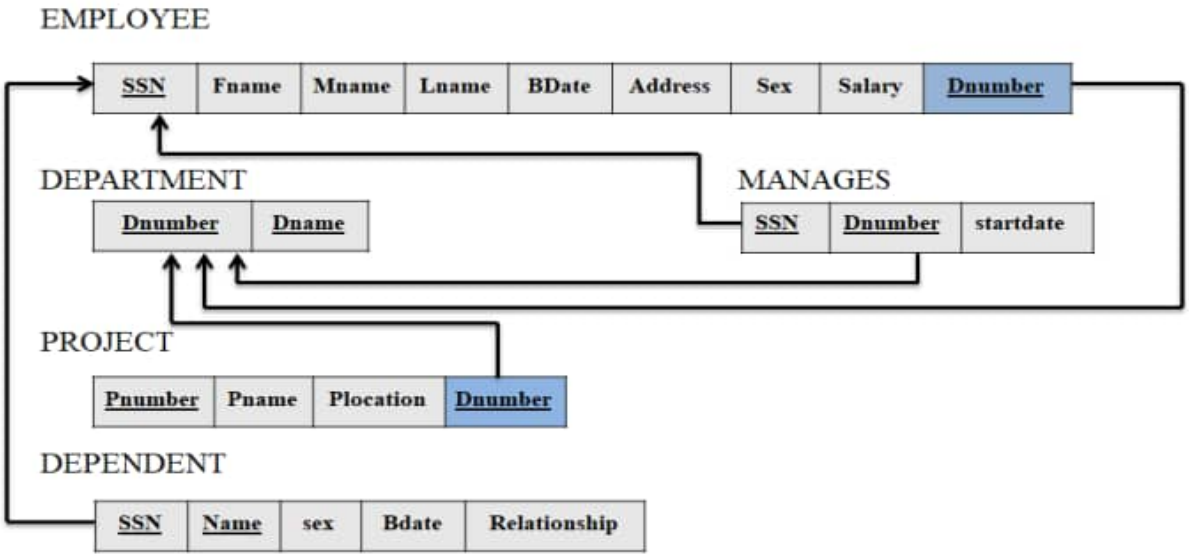
Method 3: Cross reference approach

- Create a third relation comprising primary key of both entity sets.



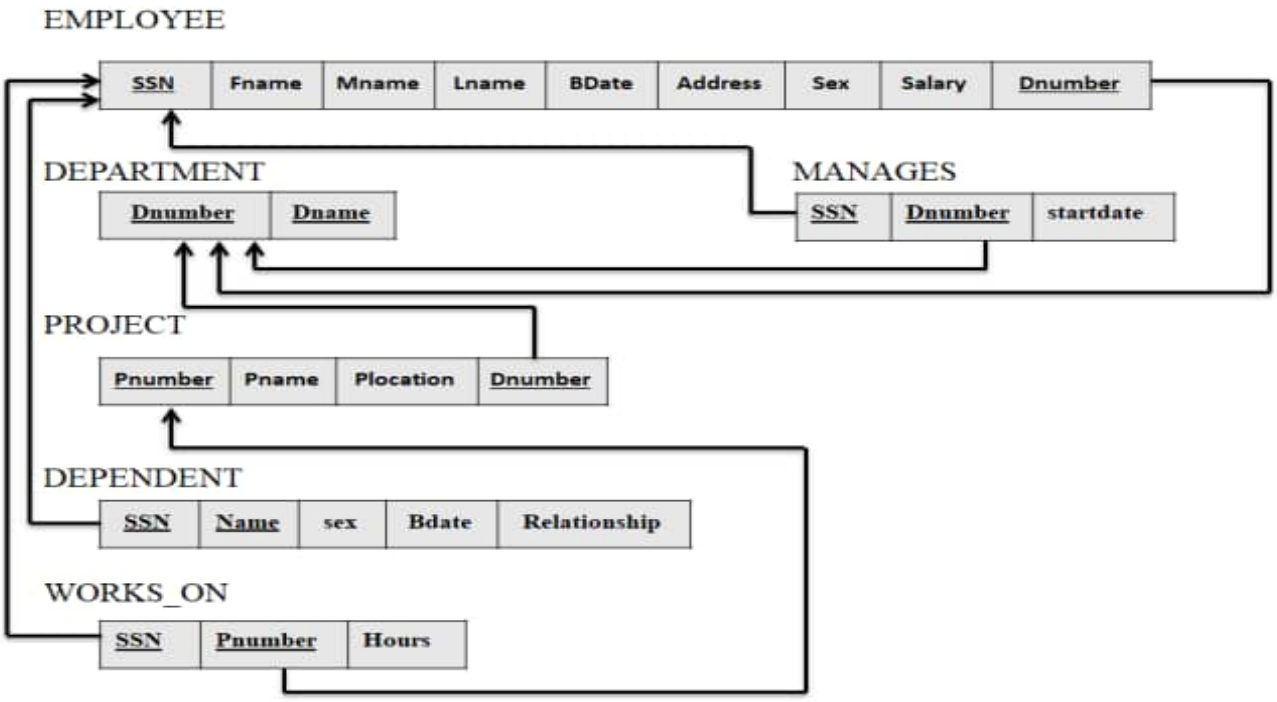
Step 4 − Conversion of one-to-many relationship

- For each one to many relationships, modify the M side to include the Primary key of one side as a foreign key.
- If relationships consist of attributes, include them as well.



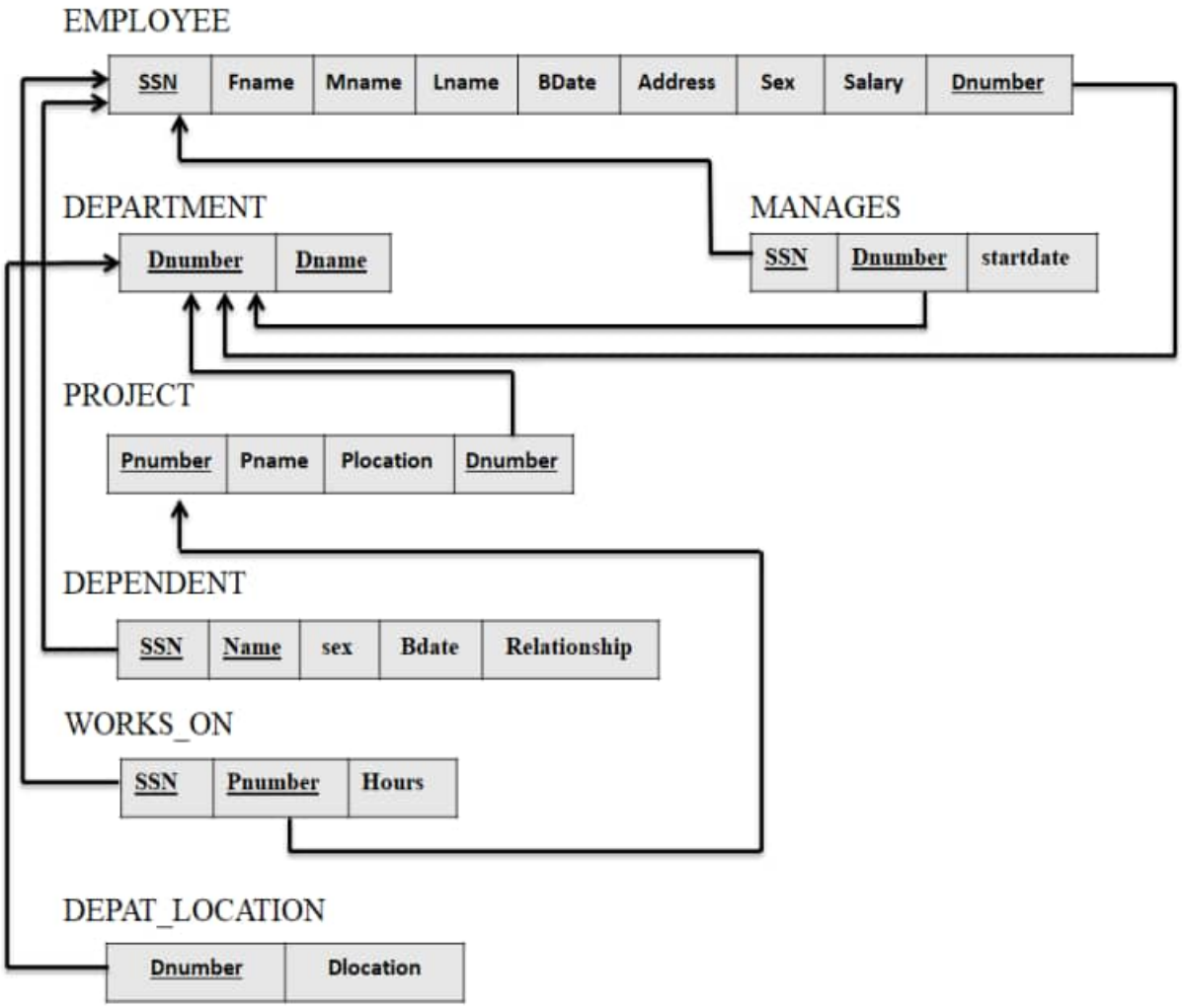
Step 5 − Conversion of many-many relationship

- For each many-many relationship, create a separate table including the Primary key of both the entity sets as foreign keys in the new table.
- Declare the combination of foreign keys as Primary key for the new table.
- If relationships consist of attributes, include them also in the new table.



Step 6 − Conversion of multivalued attributes

- For each multivalued attribute create a separate table and include the Primary key of the present table as foreign key.
- Declare the combination of foreign key and multivalued attribute as Primary keys.



Step 7 − Conversion of n-ary relationship

- For each n-ary relationship create a separate table and include the P key of all entities as foreign key.
- Declare the combination of foreign keys as P key.