Logical Design

Database Design

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Relational Database: Definitions

- Relational database: a set of relations
- Relation: made up of 2 parts:
  - Schema : specifies name of relation, plus name and type of each column.
    - e.g., Students(<u>sid: string</u>, name: string, login: string, age: integer, gpa: real).
  - Instance : a table, with rows and columns.
    #Rows = cardinality, #fields = degree / arity.
- Can think of a relation as a set of rows or tuples (all rows are distinct).

Example Instance of Students Relation

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

- Cardinality = 3, degree = 5, all rows distinct

Relational Query Languages

- A major strength of the relational model: supports simple, powerful *querying* of data.
- Queries can be written intuitively, and the DBMS is responsible for efficient evaluation.
    - The key: precise semantics for relational queries.
    - Allows the optimizer to extensively re-order operations, and still ensure that the answer does not change.

The SQL Query Language

- Developed by IBM (system R) in the 1970s
- Data Definition Language (DDL)
  - create, modify, delete relations
  - specify constraints
  - administer users, security, etc.
- Data Manipulation Language (DML)
  - Specify queries to find tuples that satisfy criteria
  - add, modify, remove tuples

Creating Relations in SQL

- Creates the Students relation. Observe that the type (domain) of each field is specified, and enforced by the DBMS whenever tuples are added or modified.
- As another example, the Enrolled table holds information about courses that students take.

```
CREATE TABLE Students
        (sid CHAR(20),
         name CHAR(20),
         login CHAR(10),
         age INTEGER,
         gpa REAL)

CREATE TABLE Enrolled
        (sid CHAR(20),
         cid CHAR(20),
         grade CHAR(2))
```

Destroying and Altering Relations

- DROP TABLE Students
  - Destroys the relation Students. The schema information and the tuples are deleted.

- ALTER TABLE Students
  ADD COLUMN firstYear: integer
  - The schema of Students is altered by adding a new field; every tuple in the current instance is extended with a null value in the new field.

Adding, Deleting and Updating Tuples

- Can insert a single tuple using
  - INSERT INTO Students (sid, name, login, age, gpa)
    VALUES (53688, 'Smith', 'smith@ee', 18, 3.2)

- Can delete all tuples satisfying some condition
  - DELETE
    FROM Students S
    WHERE S.name = 'Smith'

- Can modify the column values in an existing row
  - UPDATE Students S
    SET S.age = S.age + 1, S.gpa = S.gpa – 1
    WHERE S.sid = 53688

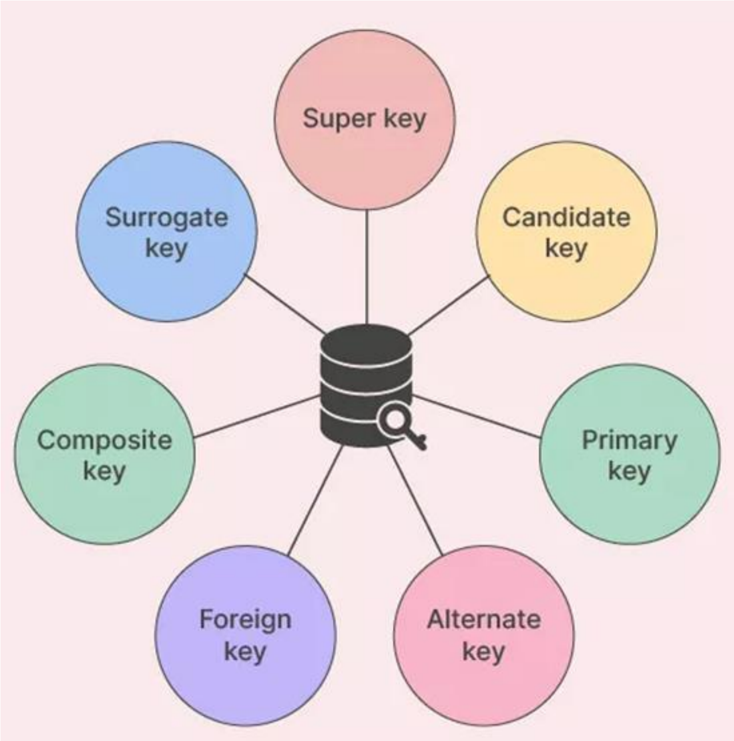
Integrity Constraints (ICs)

- IC: condition that must be true for *any* instance of the database; e.g., *domain constraints*.
  - ICs are specified when schema is defined.
  - ICs are checked when relations are modified.
- A *legal* instance of a relation is one that satisfies all specified ICs.
  - DBMS should not allow illegal instances.
- If the DBMS checks ICs, stored data is more faithful to real-world meaning.
  - Avoids data entry errors, too!

Keys

- Keys help you to identify any row of data in a table. In a real-world application, a table could contain thousands of records. Moreover, the records could be duplicated. Keys in RDBMS ensure that you can uniquely identify a table record despite these challenges.
- Allows you to establish a relationship between and identify the relation between tables.
- Help you to enforce identity and integrity in the relationship.

Type of Keys


Super key
Candidate key
Primary key
Alternate key
Foreign key
Composite key
Surrogate key

Super Key

- A super key is a group of single or multiple keys which identifies rows in a table. A super key may have additional attributes that are not needed for unique identification.

EmpSSN	EmpNum	Empname
9812345098	AB05	Shown
9876512345	AB06	Roslyn
199937890	AB07	James

In the above-given example, EmpSSN and EmpNum name are superkeys.

Candidate Key

- Candidate Key: A super key such that no proper subset is a super key within the relation. A candidate key *K* for a relation *R* has two properties:
  - Uniqueness: In each tuple of R, the values of K uniquely identify that tuple.
  - Irreducibility: No proper subset of K has the uniqueness property.

```
Student{ID, Aadhar_ID, F_name, M_name, L_name, Age}
```

Here we can see the two candidate keys ID and Aadhar_ID. So here, there are present more than one candidate keys, which can uniquely identify a tuple in a relation.

Identifying a candidate key requires that we know the "real-world" meaning of the attribute(s) involved so that we can decide whether duplicates are possible.

Primary Key

- **Primary Key** is a set of attributes (or attribute) which uniquely identify the tuples in relation or table. The candidate key that is selected to identify tuples uniquely within the relation. The primary key is a minimal super key, so there is one and only one primary key in any relationship. For example,

```
Student{ID, Aadhar_ID, F_name, M_name, L_name, Age}
```

Here only ID or Aadhar_ID can be primary key because the name, age can be same, but ID or Aadhar_ID can't be same.

- Two rows can't have the same primary key value
- It must for every row to have a primary key value.
- The primary key field cannot be null.
- The value in a primary key column can never be modified or updated if any foreign key refers to that primary key.

Primary Key Constraints

- A set of fields is a (candidate) key for a relation if :
  1. No two distinct tuples can have same values in all key fields, and
  2. This is not true for any subset of the key.
  - Part 2 false? A superkey.
  - If there's >1 key for a relation, one of the keys is chosen (by DBA) to be the primary key.
- E.g., sid is a key for Students. (What about name?) The set {sid, gpa} is a superkey.

Alternate Key

- **Alternate Key:** The candidate keys that are not selected to be the primary key are called alternate keys. This is a column or group of columns in a table that uniquely identify every row in that table. A table can have multiple choices for a primary key but only one can be set as the primary key. All the keys which are not primary key are called an Alternate Key.

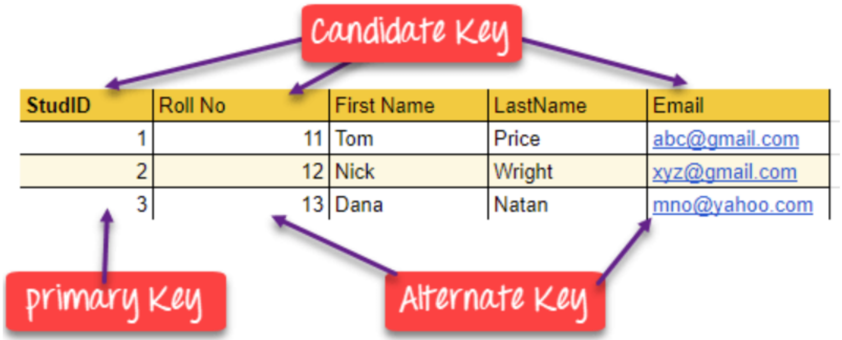
In this table, StudID, Roll No, Email are qualified to become a primary key. But since StudID is the primary key, Roll No, Email becomes the alternative key.

StudID	Roll No	First Name	LastName	Email
1	11	Tom	Price	abc@gmail.com
2	12	Nick	Wright	xyz@gmail.com
3	13	Dana	Natan	mno@yahoo.com

Example

Candidate key Example: In the given table Stud ID, Roll No, and email are candidate keys which help us to uniquely identify the student record in the table.

StudID	Roll No	First Name	LastName	Email
1	11	Tom	Price	abc@gmail.com
2	12	Nick	Wright	xyz@gmail.com
3	13	Dana	Natan	mno@yahoo.com



Candidate Key in DBMS

Foreign Key

- Foreign Key: is a column that creates a relationship between two tables. The purpose of Foreign keys is to maintain data integrity and allow navigation between two different instances of an entity. An attribute, or set of attributes, within one relation that matches the candidate key of some (possibly the same) relation.

Foreign Key

DeptCode	DeptName
001	Science
002	English
005	Computer

Teacher ID	Fname	Lname
B002	David	Warner
B017	Sara	Joseph
B009	Mike	Brunton

Dep 1 M Term

In this table, adding the foreign key in Deptcode to the Teacher name, we can create a relationship between the two tables.

Teacher ID	DeptCode	Fname	Lname
B002	002	David	Warner
B017	002	Sara	Joseph
B009	001	Mike	Brunton

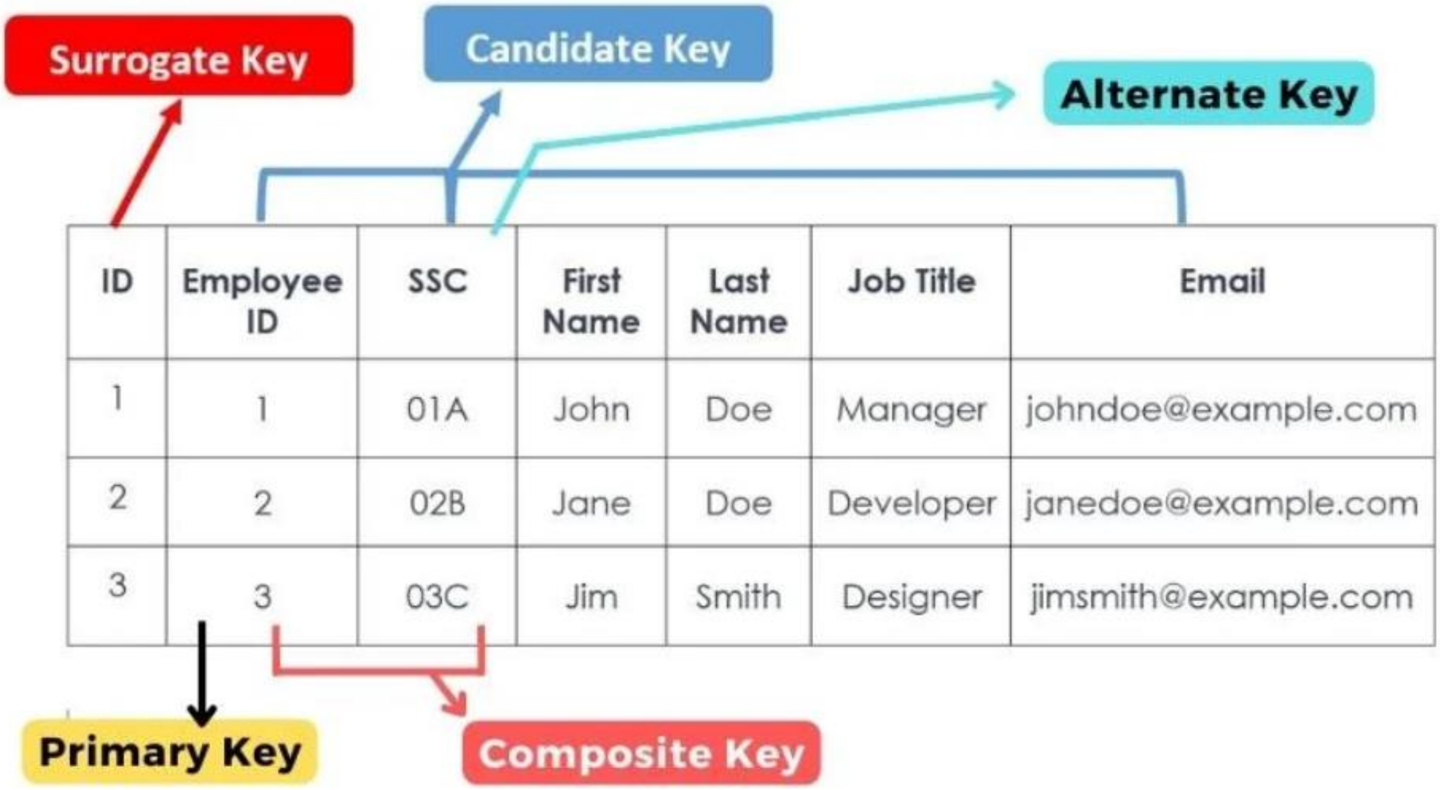
Compound Key & Composite Key

- Composite Key: a candidate key that consists of two or more attributes, (table columns) that together uniquely identify an entity occurrence (table row).
- Compound Key: is a composite key for which each attribute that makes up the key is a foreign key in its own right.

Surrogate Key

- Surrogate Key: An artificial key which aims to uniquely identify each record is called a surrogate key. These kind of key are unique because they are created when you don't have any natural primary key.
  - A common example of surrogate key is auto-incrementing integer as primary key in a table.

Type of Keys



ID	Employee ID	SSC	First Name	Last Name	Job Title	Email
1	1	01A	John	Doe	Manager	johndoe@example.com
2	2	02B	Jane	Doe	Developer	janedoe@example.com
3	3	03C	Jim	Smith	Designer	jimsmith@example.com

Primary and Candidate Keys in SQL

- Possibly many candidate keys (specified using UNIQUE), one of which is chosen as the primary key.
  - "For a given student and course, there is a single grade."
  - "Students can take only one course, and receive a single grade for that course; further, no two students in a course receive the same grade."
  - Used carelessly, an IC can prevent the storage of database instances that arise in practice!

```
CREATE TABLE Enrolled
  (sid CHAR(20)
   cid  CHAR(20),
   grade CHAR(2),
   PRIMARY KEY (sid,cid))
```

```
CREATE TABLE Enrolled
  (sid CHAR(20)
   cid  CHAR(20),
   grade CHAR(2),
   PRIMARY KEY  (sid),
   UNIQUE (cid, grade))
```

Foreign Keys, Referential Integrity

- Foreign key : Set of fields in one relation that is used to `refer' to a tuple in another relation. (Must correspond to primary key of the second relation.) Like a `logical pointer'.
- E.g. sid is a foreign key referring to Students:
  - Enrolled(sid: string, cid: string, grade: string)
  - If all foreign key constraints are enforced, referential integrity is achieved, i.e., no dangling references.

Foreign Keys in SQL

- Only students listed in the Students relation should be allowed to enroll for courses.

```
CREATE TABLE Enrolled
  (sid CHAR(20),  cid CHAR(20),  grade CHAR(2),
   PRIMARY KEY (sid,cid),
   FOREIGN KEY (sid) REFERENCES Students )
```

Enrolled

sid	cid	grade
53666	Carnatic101	C
53666	Reggae203	B
53650	Topology112	A
53666	History105	B

FOREIGN Key

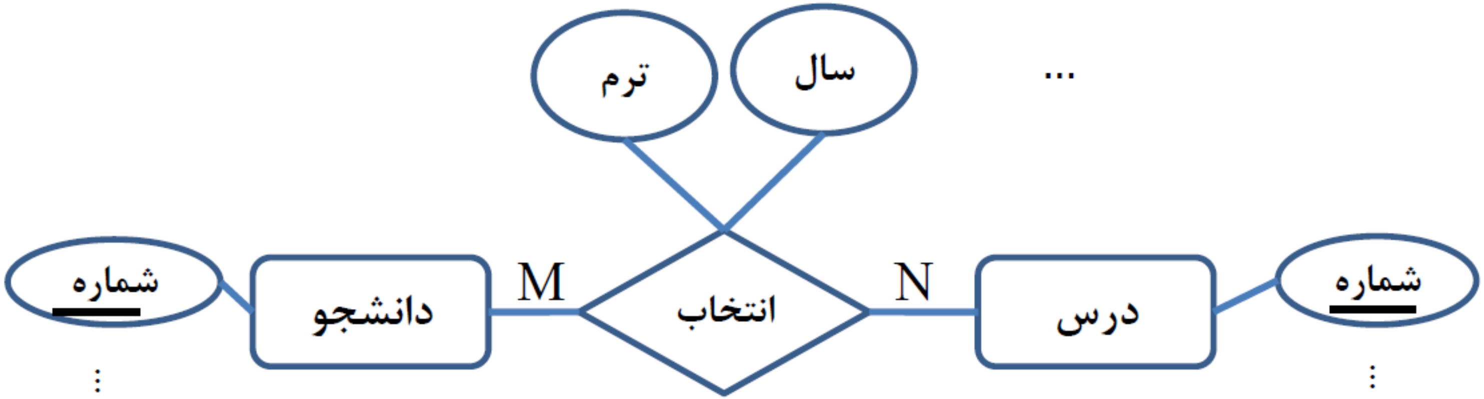
Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

PRIMARY Key

1) Degree=2 & Cardinality=M:N

- One Table for Student
- One Table for Course
- One Table for Relationship



1) Degree=2 & Cardinality=M:N

STT

STID	STNAME	STLEV	STMJR	STDEID
p.k. 777	st7	bs	phys	d11
888	st8	ms	math	d12
444	st4	ms	phys	d11
⋮	⋮	⋮	⋮	⋮

COT

COID	COTITLE	CREDIT	COTYPE	CEDEID
p.k. ⋮	⋮	⋮	⋮	⋮
co3	programming	4	t (تئوری)	d13
⋮	⋮	⋮	⋮	⋮

1) Degree=2 & Cardinality=M:N

Multi-valued Composite Attribute

STCOT

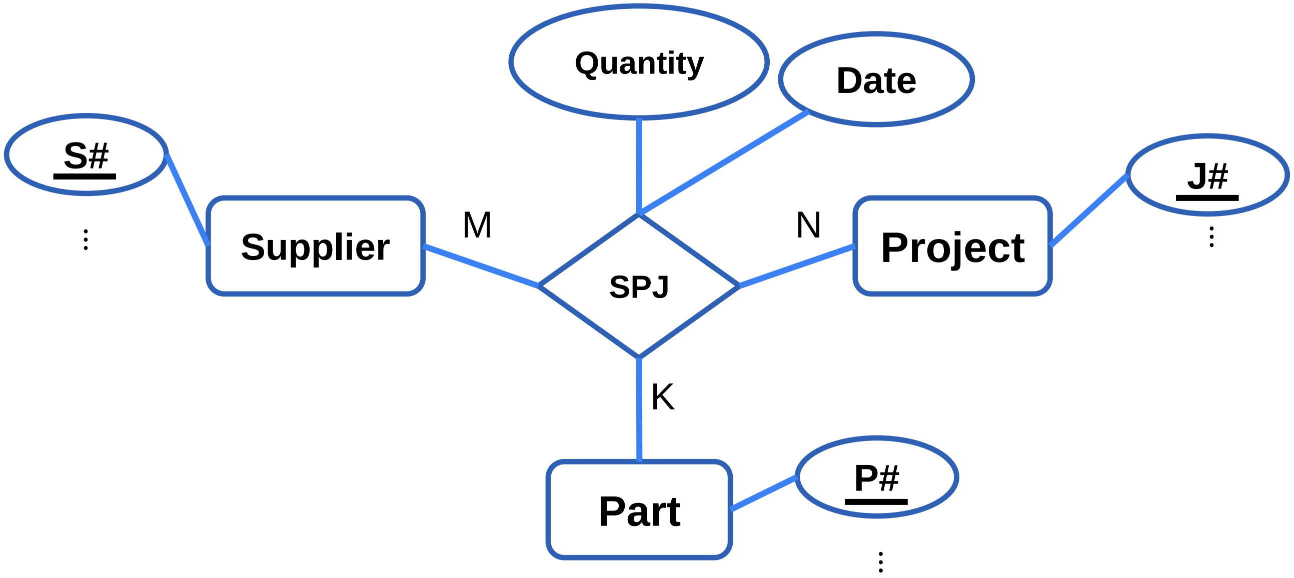
STID	COID	TR	YR
⋮	⋮	⋮	⋮
888	co2	1	87
888	co3	1	87
444	co2	1	87

p.k

Foregien Key

Define key for having cardinality M:N

2) Degree>=2 & Cardinality=M:N



2) Degree>=2 & Cardinality=M:N

Supplier

S# (p.k.)	SNAME	CITY	…
s1	…	c1	…
s2	…	c1	…
⋮	⋮	⋮	⋮

Part

P# (p.k.)	PNAME	CITY	…
p1	…	c1	…
p2	…	c2	…
⋮	⋮	⋮	⋮

Project

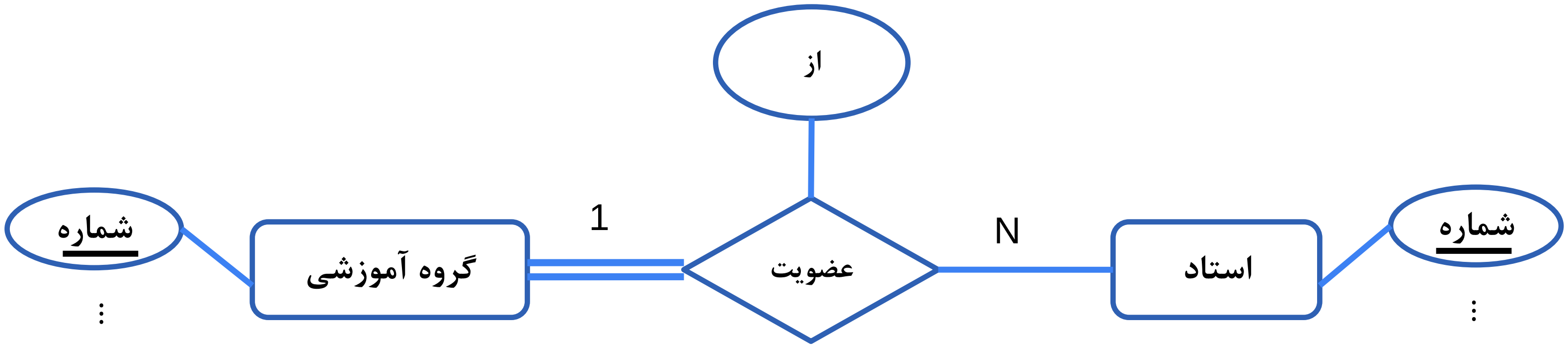
J# (p.k.)	JNAME	CITY	…
j1	…	c2	…
j2	…	c1	…
⋮	⋮	⋮	⋮

If Date is a multivalued attribute

SPJ

S#	P# (p.k.)	J#	Date	QTY
s1	p1	j1	d1	100
s1	p1	j1	d2	50
⋮	⋮	⋮	⋮	⋮

3) Degree=2 & Cardinality=1:N



3) Degree=2 & Cardinality=1:N

- First Solution:

DEPT (p.k. = DEID)

DEID	DETITLE	…	DEPHONE
D11	Phys	…	…
D12	Math	…	…
⋮	⋮	⋮	⋮

PROF (p.k. = PRID)

PRID	PRNAME	RANK	…	FROM	DEID
Pr100	…	استاد	…	d1	D13
Pr200	…	استادیار	…	d2	D11
Pr300	…	دانشیار	…	?	?

3) Degree=2 & Cardinality=1:N

- Second Solution:

DEPT

DEID	DETITLE	...	DEPHONE
D11	Phys	...	...
D12	Math	...	...
⋮	⋮	⋮	⋮

PROF

PRID	PRNAME	RANK	...
Pr100	...	استاد	...
Pr200	...	استادیار	...
Pr300	...	دانشیار	...

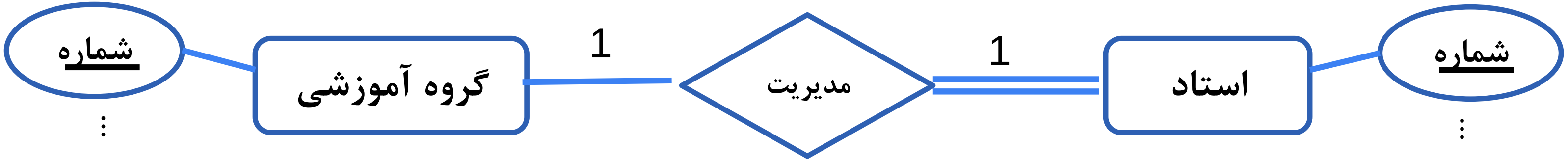
PD

PRID	DEID	FROM
Pr100	D11	d1
Pr200	D12	d2
Pr300	D12	d3

3) Degree=2 & Cardinality=1:N

- When use which solution?
  - Performance because of join
  - Disk
  - More null values

4) Degree=2 & Cardinality=1:1



- First solution: If all relationships are total: One table!

4) Degree=2 & Cardinality=1:1

- Second solution:

DEPT

p.k DEID	DETITLE	…	DEPHONE	PRID
D11	Phys	…	…	…
D12	Math	…	…	…
⋮	⋮	⋮	⋮	⋮

PROF

p.k PRID	PRNAME	RANK	…
Pr100	…	استاد	…
Pr200	…	استادیار	…
Pr300	…	دانشیار	…
⋮	⋮	⋮	⋮

4) Degree=2 & Cardinality=1:1

- Third solution:

DEPT

p.k DEID	DETITLE	…	DEPHONE
D11	Phys	…	…
D12	Math	…	…
⋮	⋮	⋮	⋮

PD

p.k DEID	PRID
D11	Pr100
D12	Pr200
⋮	⋮

PROF

p.k PRID	PRNAME	RANK	…
Pr100	…	استاد	…
Pr200	…	استادیار	…
Pr300	…	دانشیار	…
⋮	⋮	⋮	⋮

References

- Chapter 4 of FUNDAMENTALS OF Database Systems, SEVENTH EDITION
- Chapter 13 of Database Systems A Practical Approach to Design, Implementation, and Management, SIXth edition
- Chapter 6 of DATABASE SYSTEM CONCEPTS, S I XTH E D I T I ON.