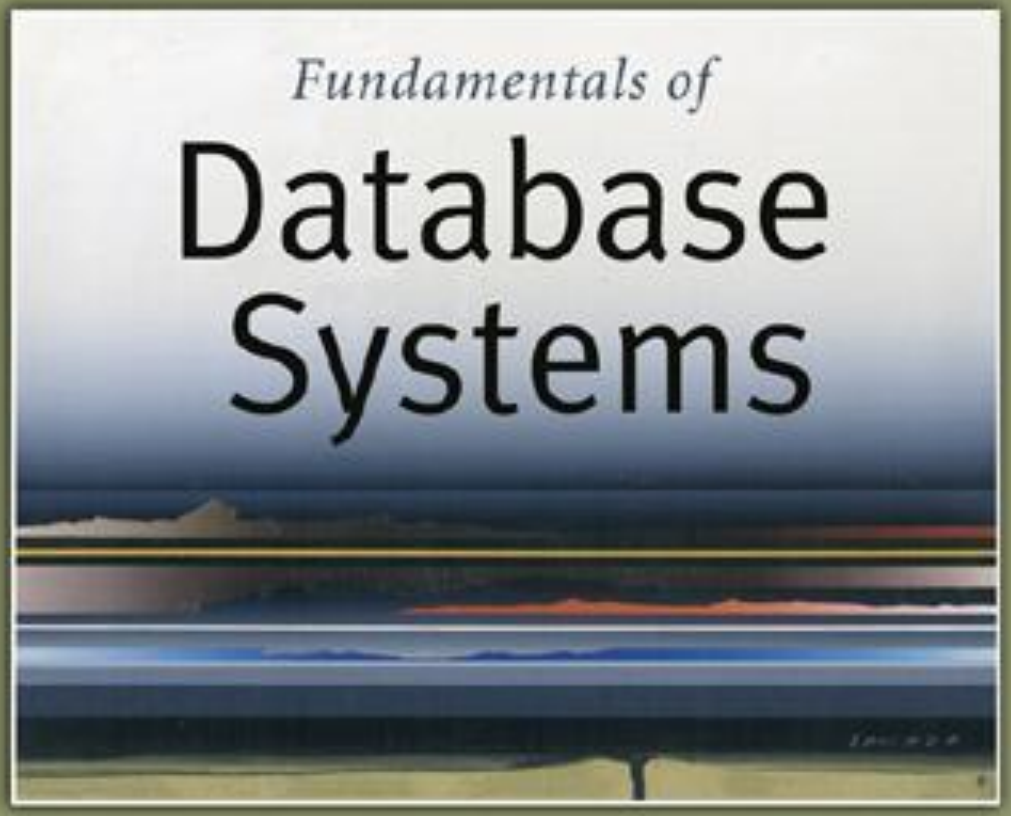

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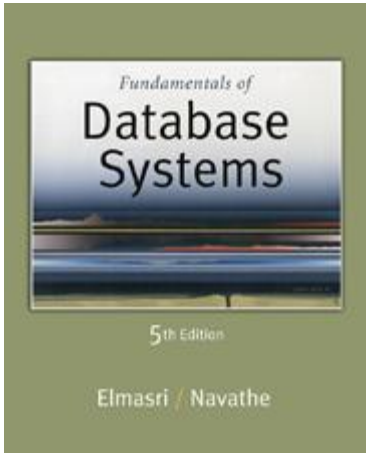
Chapter 10

Functional Dependencies and Normalization for Relational Databases



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Chapter Outline

- 1 Informal Design Guidelines for Relational Databases
  - 1.1Semantics of the Relation Attributes
  - 1.2 Redundant Information in Tuples and Update Anomalies
  - 1.3 Null Values in Tuples
  - 1.4 Spurious Tuples
- 2 Functional Dependencies (FDs)
  - 2.1 Definition of FD
  - 2.2 Inference Rules for FDs
  - 2.3 Equivalence of Sets of FDs
  - 2.4 Minimal Sets of FDs

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Chapter Outline

- 3 Normal Forms Based on Primary Keys
  - 3.1 Normalization of Relations
  - 3.2 Practical Use of Normal Forms
  - 3.3 Definitions of Keys and Attributes Participating in Keys
  - 3.4 First Normal Form
  - 3.5 Second Normal Form
  - 3.6 Third Normal Form
- 4 General Normal Form Definitions (4NF For Multiple Keys)
- 5 BCNF (Boyce-Codd Normal Form)

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1 Informal Design Guidelines for Relational Databases (1)

- What is relational database design?
  - The grouping of attributes to form "good" relation schemas
- Two levels of relation schemas
  - The logical "user view" level
  - The storage "base relation" level
- Design is concerned mainly with base relations
- What are the criteria for "good" base relations?

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Informal Design Guidelines for Relational Databases (2)

- We first discuss informal guidelines for good relational design
- Then we discuss formal concepts of functional dependencies and normal forms
  - - 1NF (First Normal Form)
  - - 2NF (Second Normal Form)
  - - 3NF (Third Normal Form)
  - - BCNF (Boyce-Codd Normal Form)
- Additional types of dependencies, further normal forms, relational design algorithms by synthesis are discussed in Chapter 11

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1.1 Semantics of the Relation Attributes

- GUIDELINE 1: Informally, each tuple in a relation should represent one entity or relationship instance. (Applies to individual relations and their attributes).
  - Attributes of different entities (EMPLOYEEs, DEPARTMENTs, PROJECTs) should not be mixed in the same relation
  - Only foreign keys should be used to refer to other entities
  - Entity and relationship attributes should be kept apart as much as possible.
- Bottom Line: *Design a schema that can be explained easily relation by relation. The semantics of attributes should be easy to interpret.*

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Figure 10.1 A simplified COMPANY relational database schema

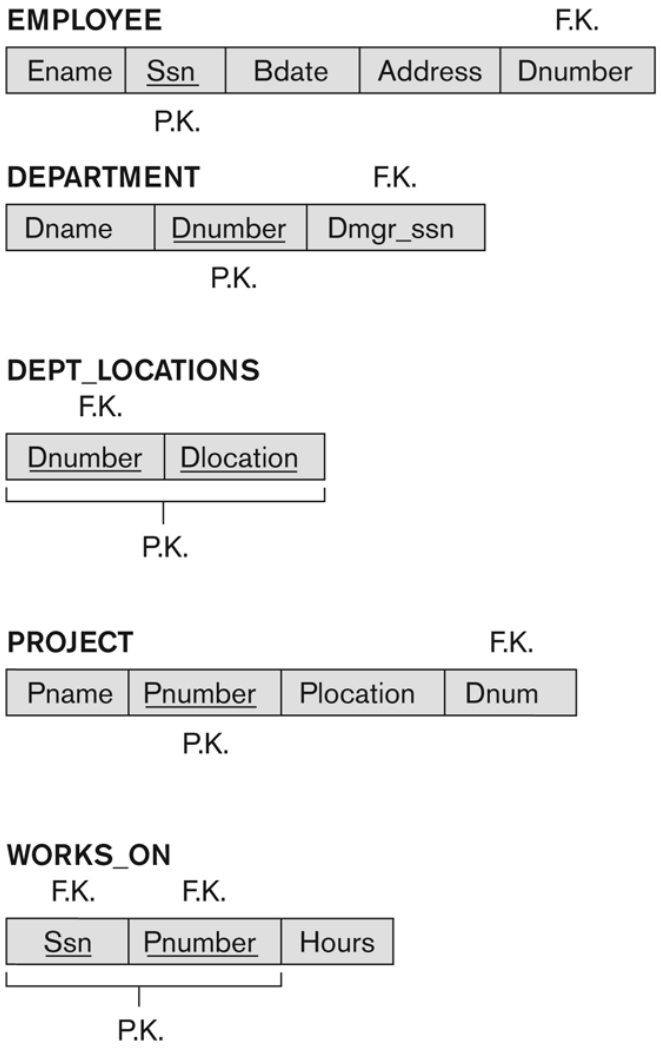

Figure 10.1
A simplified COMPANY relational database schema.

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1.2 Redundant Information in Tuples and Update Anomalies

- Information is stored redundantly
  - Wastes storage
  - Causes problems with update anomalies
    - Insertion anomalies
    - Deletion anomalies
    - Modification anomalies

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EXAMPLE OF AN UPDATE ANOMALY

- Consider the relation:
  - EMP_PROJ(Emp#, Proj#, Ename, Pname, No_hours)
- Update Anomaly:
  - Changing the name of project number P1 from “Billing” to “Customer-Accounting” may cause this update to be made for all 100 employees working on project P1.

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EXAMPLE OF AN INSERT ANOMALY

- Consider the relation:
  - EMP_PROJ(Emp#, Proj#, Ename, Pname, No_hours)
- Insert Anomaly:
  - Cannot insert a project unless an employee is assigned to it.
- Conversely
  - Cannot insert an employee unless an he/she is assigned to a project.

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EXAMPLE OF AN DELETE ANOMALY

- Consider the relation:
  - EMP_PROJ(Emp#, Proj#, Ename, Pname, No_hours)
- Delete Anomaly:
  - When a project is deleted, it will result in deleting all the employees who work on that project.
  - Alternately, if an employee is the sole employee on a project, deleting that employee would result in deleting the corresponding project.

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Example of Anomalies

- **Insertion anomaly:**
- If a tuple is inserted in referencing relation and referencing attribute value is not present in referenced attribute, it will not allow inserting in referencing relation.
- For Example, If we try to insert a record in STUDENT_COURSE with STUD_NO =7, it will not allow.

STUDENT

STUD_NO	STUD_NAME	STUD_PHONE	STUD_STATE	STUD_COUNTRY	STUD_AGE
1	RAM	9716271721	Haryana	India	20
2	RAM	9898291281	Punjab	India	19
3	SUJIT	7898291981	Rajsthan	India	18
4	SURESH		Punjab	India	21

Course

Course_Id	C_name
C1	DBMS
C2	CN
C3	Java
C4	Python

STUDENT_COURSE

STUD_NO	COURSE_NO	COURSE_NAME
1	C1	DBMS
2	C2	Computer Networks
1	C2	Computer Networks

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- **Deletion and Update anomaly:**
- If a tuple is deleted or updated from referenced relation and referenced attribute value is used by referencing attribute in referencing relation, it will not allow deleting the tuple from referenced relation.
- For Example, If we try to delete a record from STUDENT with STUD_NO =1, it will not allow.

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Figure 10.3 Two relation schemas suffering from update anomalies

Figure 10.3
Two relation schemas suffering from update anomalies.
(a) EMP_DEPT and
(b) EMP_PROJ.

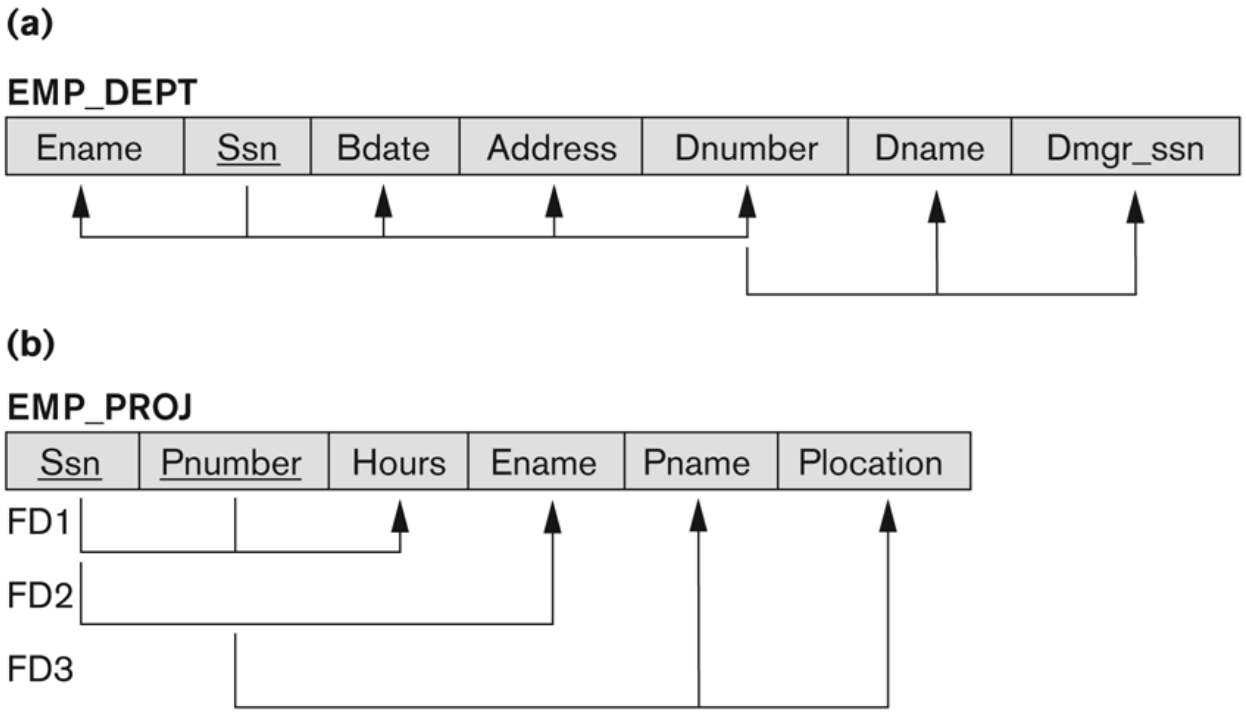

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Figure 10.4 Example States for EMP_DEPT and EMP_PROJ

Redundancy

EMP_DEPT

Ename	Ssn	Bdate	Address	Dnumber	Dname	Dmgr_ssn
Smith, John B.	123456789	1965-01-09	731 Fondren, Houston, TX	5	Research	333445555
Wong, Franklin T.	333445555	1955-12-08	638 Voss, Houston, TX	5	Research	333445555
Zelaya, Alicia J.	999887777	1968-07-19	3321 Castle, Spring, TX	4	Administration	987654321
Wallace, Jennifer S.	987654321	1941-06-20	291 Berry, Bellaire, TX	4	Administration	987654321
Narayan, Ramesh K.	666884444	1962-09-15	975 FireOak, Humble, TX	5	Research	333445555
English, Joyce A.	453453453	1972-07-31	5631 Rice, Houston, TX	5	Research	333445555
Jabbar, Ahmad V.	987987987	1969-03-29	980 Dallas, Houston, TX	4	Administration	987654321
Borg, James E.	888665555	1937-11-10	450 Stone, Houston, TX	1	Headquarters	888665555

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Guideline to Redundant Information in Tuples and Update Anomalies

- GUIDELINE 2:
  - Design a schema that does not suffer from the insertion, deletion and update anomalies.
  - If there are any anomalies present, then note them so that applications can be made to take them into account.

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1.3 Null Values in Tuples

- GUIDELINE 3:
  - Relations should be designed such that their tuples will have as few NULL values as possible
  - Attributes that are NULL frequently could be placed in separate relations (with the primary key)
  - It causes confusion in COUNT and SUM operation.
  - If NULL value comes in comparision with SELECT or JOIN operation, the result will unpredictable.

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- Reasons for nulls:
  - Attribute not applicable or invalid
  - Attribute value unknown (may exist)
  - Value known to exist, but unavailable

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1.4 Spurious Tuples

- Bad designs for a relational database may result in erroneous results for certain JOIN operations
- The "lossless join" property is used to guarantee meaningful results for join operations(LOS

- GUIDELINE 4:
  - The relations should be designed to satisfy the lossless join condition i.means No spurious tuples should be generated by doing a natural-join of any relations.

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Spurious Tuples (2)

- There are two important properties of decompositions:
  a) Non-additive or losslessness of the corresponding join
  b) Preservation of the functional dependencies.

- Note that:
  - Property (a) is extremely important and *cannot* be sacrificed.
  - Property (b) is less stringent and may be sacrificed. (See Chapter 11).

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Example:

- The relation EMP_PROJ is decomposed into two relations: EMP_LOCS and EMP_PROJ1.
- by re-joining of these two relations will generate some spurious tuples.
- So the join operation will not get original EMP_Proj relation.

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Example

- **Spurious Tuples Example**
- Consider the poorly designed relations EMP_PROJ1

EMPNO	PNO	ENAME	PNAME	PLOC
1	P1	A	UNIX	BLORE
1	P2	A	C++	CHENNAI
2	P1	B	UNIX	BLORE
2	P2	B	C++	CHENNAI
3	P1	C	UNIX	BLORE

- This poorly designed table is split on the basis of ploc(non PK)We get EMP-LOC AND EMP-PROJ

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EMP-LOC

ENAME	PLOC
A	BLORE
A	CHENNAI
B	BLORE
B	CHENNAI
C	BLORE

EMP-PROJ

EMPNO	PNO	PNAME	PLOC
1	P1	UNIX	BLORE
1	P2	C++	CHENNAI
2	P1	UNIX	BLORE
2	P2	C++	CHENNAI
3	P1	UNIX	BLORE

- NOW IF EMP-LOC AND EMP-PROJ JOINED ON THE BASIS OF PLOC, will not get proper output
- We will not get original table.

eno	pno	ename	pname	ploc	eno	pno	ploc
3	p1	C	Unix	Blore	1	p1	Blore
2	p1	B	Unix	Blore	1	p1	Blore
2	p2	B	C++	Chennai	1	p2	Chennai
1	p2	A	C++	Chennai	1	p2	Chennai
3	p1	C	Unix	Blore	2	p1	Blore
2	p1	B	Unix	Blore	2	p1	Blore
2	p2	B	C++	Chennai	2	p2	Chennai
1	p2	A	C++	Chennai	2	p2	Chennai
3	p1	C	Unix	Blore	3	p1	Blore
2	p1	B	Unix	Blore	3	p1	Blore

(10 rows)

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2.1 Functional Dependencies (1)

- Functional dependencies (FDs)
  - Are used to specify *formal measures* of the "goodness" of relational designs
  - And keys are used to define **normal forms** for relations
  - Are **constraints** that are derived from the *meaning* and *interrelationships* of the data attributes
- A set of attributes X *functionally determines* a set of attributes Y if the value of X determines a unique value for Y

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Keys:

- 1. Superkey:
- All possible combination of keys are called superkeys.
- Uniquely identify record.
- Superkey is a superset, we can derive other keys from superkey.

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- {ID},{SSN},
- {ID,Name},{Name,SSN}
- {ID,SSN},{ID,phone},
- ID,email
- Name,email
- Name,ssn,email
- Id,SSN,Phone
- {Name,Salary}
- **Here, {Name,Salary} can't become a superkey.**

Employee

ID	Name	SSN	Salary	Phone	Email
101	John	AA	50000	12	j@sw
102	Robin	BB	60000	13	r@yh
103	Alya	CC	35000	14	a@hm
104	Yusuf	DD	68000	15	y@ch
105	John	EE	62000	89	j@in
106	Raj	FF	45000	87	r@au
107	Jayant	GG	25000	45	j@us
108	John	HH	35000	15	j@de
109	Neil	II	25000	12	n@uk

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Candidate key

- Minimal set of superkey.
- From the following set of superkeys:

  {ID},{SSN},{ID,Name},{Name,SSN},{ID,SSN},{ID,phone},
  {ID,email},{Name,email},{Name,ssn,email},{Id,SSN,Phone},
  {Name,Salary}
- We can select candidate key (minimal set)
- Such as,
- {ID} and {SSN} can be a separate candidate keys.
- {email}, {Name,Phone}
- {ID,Name} cant be candidate key, bcz ID is a part of another candidate key.

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Primary key

- Primary key should be unique and not null
- Example:

Candidate keys in above examples are:

{ID},{SSN},{Email},{Name,phone}

Primary key is :{ID} or {SSN}

Not both.

{ID} is preferred.

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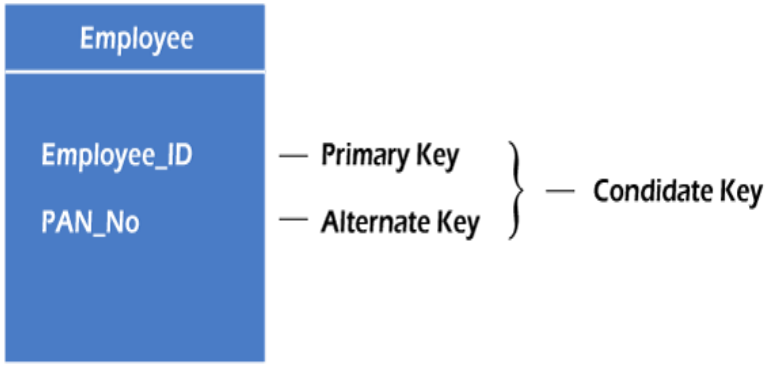
Alternate Keys

The candidate key other than primary key are called alternate keys.



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Unique key & Composite key

- It should contain unique values, but accept NULL values.
- Example:
- {Name,Phone} and {email} can be a unique keys.

- Composite key:
- Combination of Two or More attribute
- Example:
- {Name,Phone}
- {ID,Phone}
- {ID,Name}.. etc.

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Foreign key

- A foreign key in DBMS is a field that establishes and maintains a link between two separate tables.
- It acts as a constraint ensuring data and referential integrity within relational databases.
- Using foreign keys ensures that the data stored in different tables are consistent, helping maintain the relationship between the two tables while preventing any unauthorized modifications.
- In addition, they can also be used to create connections among multiple entities to organize information for better retrieval from the database.

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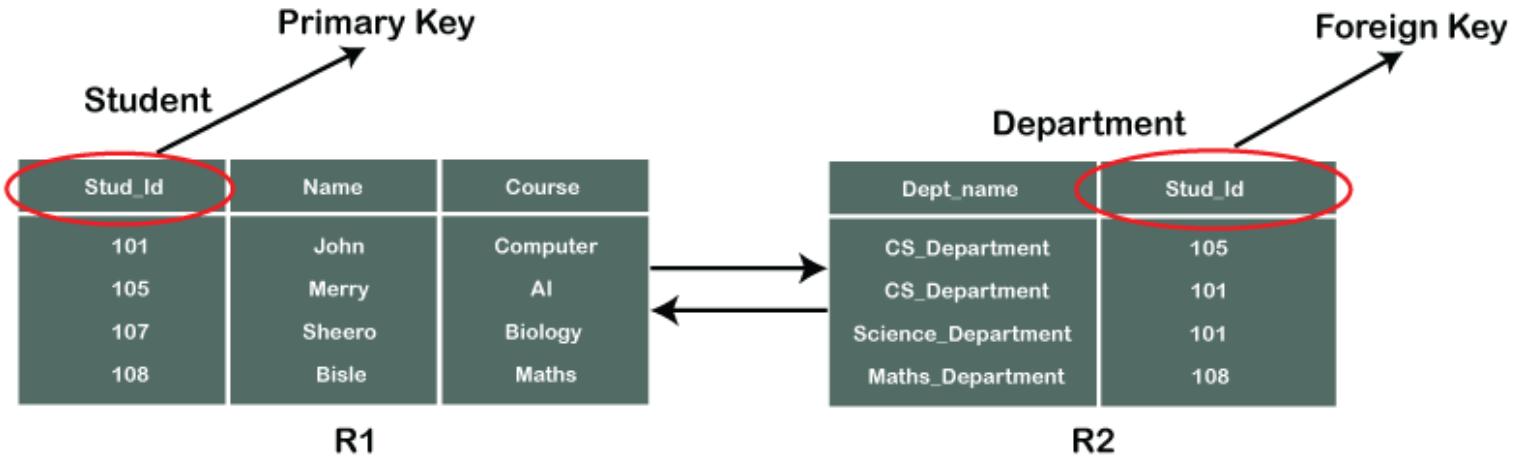
Example

- This foreign key relationship ensures referential integrity between the two tables.
- It means that every value in the Stud_id column of the Department table must correspond to a valid Stud_id in the Student table.
- For example, you can't insert a record into the Department table with a Stud_id that doesn't exist in the Courses table. This helps to maintain consistency



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Proper subset:

- A proper subset of a set A is a subset of A that is not equal to A.
- In other words, if B is a proper subset of A, then all elements of B are in A but A contains at least one element that is not in B.
- if A={1,3,5} then B={1,5} is a proper subset of A.
- The set C={1,3,5} is a subset of A, but it is not a proper subset of A since C=A.
- Example:
- Let us consider in relation R(A,B,C,D),
- If {A,B,C} is a super key, then proper subset of this super key are:
- {A},
- {B}
- {C}
- {A,B}
- {A,C}
- {B,C}

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Functional Dependencies (2)

- X -> Y holds if whenever two tuples have the same value for X, they *must have* the same value for Y
  - For any two tuples t1 and t2 in any relation instance r(R): If t1[X]=t2[X], *then* t1[Y]=t2[Y]
- X -> Y in R specifies a *constraint* on all relation instances r(R)
- Written as X -> Y; can be displayed graphically on a relation schema as in Figures. (denoted by the arrow:).
- FDs are derived from the real-world constraints on the attributes

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Examples of FD constraints (1)

- Social security number determines employee name
  - SSN -> ENAME
- Project number determines project name and location
  - PNUMBER -> {PNAME, PLOCATION}
- Employee ssn and project number determines the hours per week that the employee works on the project
  - {SSN, PNUMBER} -> HOURS

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Examples of FD constraints (2)

- An FD is a property of the attributes in the schema R
- The constraint must hold on *every* relation instance r(R)
- If K is a key of R, then K functionally determines all attributes in R
  - (since we never have two distinct tuples with t1[K]=t2[K])

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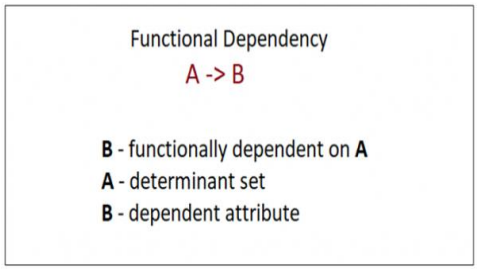
functional dependency

- The functional dependency is a relationship that exists between two attributes, where one set can accurately determine the value of other sets.
- It is denoted as **X** → **Y**, where X is a set of attributes that is capable of determining the value of Y.
- **X** is called **Determinant**, while on the right side, **Y** is called the **Dependent**.



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Example

- Assume we have an employee table with attributes:
  - Emp_Id, Emp_Name, Emp_Address.
- Here Emp_Id attribute can uniquely identify the Emp_Name attribute of employee table because if we know the Emp_Id, we can tell that employee name associated with it.
- Functional dependency can be written as:

$$\text{Emp\_Id} \rightarrow \text{Emp\_Name}$$

- We can say that Emp_Name is functionally dependent on Emp_Id.

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Example

- FD: X -> Y

X	Y
1	1
2	1
3	2
4	3

- FD: if t1.X = t2.X
- then t1.Y = t2.Y
- Here,
- if t1.x= 1 t2.x = 2 false

- In this example,

	X	Y
	1	1
t1	2	1
	3	2
	4	3
t2	2	5

- if t1.x= 2 t2.x = 2 true
- Then t1.Y=1 t2.Y =5 false

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- Consider the following table:

RNO	Name	Marks	Dept	Course
1	A	78	CS	C1
2	B	60	EX	C1
3	A	78	CS	C2
4	B	60	ES	C3
5	C	80	IT	C3
6	D	80	EC	C2

- RNO -> Name
- FD
- Name -> RNO
- FD doesn't exist
- RNO -> Marks
- FD exist
- Name –Marks
- FD exist
- Dept -> Course
- FD doesn't exist
- Marks -> Dept
- FD doesn't exist
- {RNO, Name} -> Marks
- FD exist
- {Name, Marks} -> Dept
- FD doesn't exist

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2.3 Equivalence of Sets of FDs

- Two sets of FDs F and G are **equivalent** if:
  - Every FD in F can be inferred from G, and
  - Every FD in G can be inferred from F
  - Hence, F and G are equivalent if $F^+ = G^+$
- Definition (**Covers**):
  - F **covers** G if every FD in G can be inferred from F
    - (i.e., if G^+ *subset-of* F^+)
- F and G are equivalent if F covers G and G covers F
- There is an algorithm for checking equivalence of sets of FDs

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2.4 Minimal Sets of FDs (1)

- A set of FDs is **minimal** if it satisfies the following conditions:
  1. Every dependency in F has a single attribute for its RHS.
  2. We cannot remove any dependency from F and have a set of dependencies that is equivalent to F.
  3. We cannot replace any dependency X -> A in F with a dependency Y -> A, where Y proper-subset-of X (Y subset-of X) and still have a set of dependencies that is equivalent to F.

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Minimal Sets of FDs (2)

- Every set of FDs has an equivalent minimal set
- There can be several equivalent minimal sets
- There is no simple algorithm for computing a minimal set of FDs that is equivalent to a set F of FDs
- To synthesize a set of relations, we assume that we start with a set of dependencies that is a minimal set
  - E.g., see algorithms 11.2 and 11.4

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2.2 Inference Rules for FDs (1)

- Given a set of FDs F, we can **infer** additional FDs that hold whenever the FDs in F hold
- Armstrong's inference rules:
  - IR1. (**Reflexive**) If Y *subset-of* X, then X -> Y

    If $X \subseteq Y$ then $X \rightarrow Y$

    - **Example:**

      {Rno,Name} -> Name

      Here , name is a subset of {rno, name}

  - IR2. (**Augmentation**) If X -> Y, then XZ -> YZ
    - (Notation: XZ stands for X U Z)

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- IR3. (**Transitive**) If X -> Y and Y -> Z, then X -> Z

- IR1, IR2, IR3 form a **sound** and **complete** set of inference rules
  - These are rules hold and all other rules that hold can be deduced from these

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Inference Rules for FDs (2)

- Some additional inference rules that are useful:
  - **Decomposition:** If X -> YZ, then X -> Y and X -> Z
  - **Union:** If X -> Y and X -> Z, then X -> YZ
  - **Psuedotransitivity:** If X -> Y and WY -> Z, then WX -> Z
- The last three inference rules, as well as any other inference rules, can be deduced from IR1, IR2, and IR3 (completeness property)

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Inference Rules for FDs (3)

- **Closure** of a set F of FDs is the set F^+ of all FDs that can be inferred from F
- **Closure** of a set of attributes X with respect to F is the set X^+ of all attributes that are functionally determined by X
- X^+ can be calculated by repeatedly applying IR1, IR2, IR3 using the FDs in F

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Types of Functional dependencies

1. Full dependency
2. Partial dependancy
3. Trivial functional dependency
4. Non-Trivial functional dependency
5. Multivalued functional dependency
6. Transitive functional dependency

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Fully functional dependency

- An attribute is fully functional dependent on X and if Y is FD on X but not FD on any proper subset of X.

E_id	E_name	Department
101	A	Marketing
102	B	Production
103	C	Quality
101	B	Quality

- Here, Eid -> Dept and E_name ->Dept, these 2 functional dependencies doesn't exist.
- Hence ,
- Dept is completely depend on {Eid,Ename}.

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Partial functional dependency

- An attribute is fully functional dependent on X and if Y is FD on X but not FD on any pro[illegible] X.

E_id	E_name	Department
101	A	Marketing
102	B	Production
103	C	Quality

- Here, Eid -> Dept and E_name ->Dept, these 2 functional dependencies exist (individually).
- That means either Eid or Ename can determine Dept.
- Hence ,
- Dept is partially depend on {Eid,Ename}

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Trivial Functional Dependency:

- In , a dependent is always a subset of the determinant.
  i.e. If **X → Y** and **Y is the subset of X**, then it is called trivial functional dependency
- **For example,**
- Here, **{roll_no, name} → name** is a trivial functional dependency, since the dependent **name** is a subset of determinant set **{roll_no, name}**
  Similarly, **roll_no → roll_no** is also an example of trivial functional dependency.

roll_no	name	age
42	abc	17
43	pqr	18
44	xyz	18

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Non-trivial_Functional_Dependency

- In **Non-trivial functional dependency**, the dependent is strictly not a subset of the determinant.
- i.e. If **X → Y** and **Y is not a subset of X**, then it is called Non-trivial functional dependency.
- **For example,**
- Here, **roll_no → name** is a non-trivial functional dependency, since the dependent **name** is **not a subset of** determinant **roll_no**
- Similarly, **{roll_no, name} → age** is also a no trivial functional dependency, since **age** is **no subset of {roll_no, name}**

roll_no	name	age
42	abc	17
43	pqr	18
44	xyz	18

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Multivalued Functional Dependency

- In **Multivalued functional dependency**, attributes of the dependent set are **not dependent on each other.**
- i.e. If **a → {b, c}** and there exists **no functional dependency** between **b and c**, then it is called a **multivalued functional dependency.**
- Here, **roll_no → {name, age}** is a multival**ued** functional dependency, since the dependents **name** & **age** are **not depende**
- each other(i.e. **name → age** or **age → name does !**)

For example,

roll_no	name	age
42	abc	17
43	pqr	18
44	xyz	18
45	abc	19

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Transitive Functional Dependency

- In transitive functional dependency, dependent is indirectly dependent on determinant.
  i.e. If **a** → **b** & **b** → **c**, then according to axiom of transitivity, **a** → **c**. This is a **transitive functional dependency**
- Example:
- Here, **enrol_no** → **dept** and **dept** → **building_no**,

For example,

enrol_no	name	dept	building_no
42	abc	CO	4
43	pqr	EC	2
44	xyz	IT	1
45	abc	EC	2

- Hence, according to the axiom of transitivity, **enrol_no** → **building_no** is a valid functional dependency.
- This is an indirect functional dependency, hence called Transitive functional dependency.

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Find superkeys

- If we have ‘N’ attributes with one candidate key then the number of possible superkeys is $2^{(N-1)}$.
- Example:
- Let's say we have a relation R with attributes {a1, a2, a3} and a1 is the candidate key.
- Then, any superset of a1 is the super key.
- Here n=3, thus, we can have $2^{(3-1)}=$ 2^2= 4 ,
- four possible super keys: {a1, a1 a2, a1 a3, a1 a2 a3}.

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Examples

- **Steps to Find the Attribute Closure:**
- **Given the FD set of a Relation R, The attribute closure set S is the set of Attribute Closure A.**
  - Add A to S.
  - Recursively add attributes that can be functionally determined from attributes of the set S until done.

E-ID	E-NAME	E-CITY	E-STATE
E001	John	Delhi	Delhi
E002	Mary	Delhi	Delhi
E003	John	Noida	U.P.

- From Table 1, FDs are
- **Given R (E-ID, E-NAME, E-CITY, E-STATE)**
  FDs = { E-ID->E-NAME, E-ID->E-CITY, E-ID->E-STATE, E-CITY->E-STATE }

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- The attribute closure of E-ID can be calculated as:
- Add E-ID to the set {E-ID}
- Add Attributes that can be derived from any attribute of the set.
- As there is one other attribute remaining in relation to be derived from E-ID.
- So the result is:
- **$(E\text{-}ID)^+ = \{E\text{-}ID, E\text{-}NAME, E\text{-}CITY, E\text{-}STATE\}$**

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- Similarly,
- **$(\text{E-NAME})^{+} = \{\text{E-NAME}\}$**
- **$(\text{E-CITY})^{+} = \{\text{E-CITY, E\_STATE}\}$**
- **$(\text{E-STATE})^{+} = \{\text{ E\_STATE}\}$**

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Example

- **Find the attribute closures of $(B)^+$,given FDs R(ABCDE) = {AB->C, B->D, C->E, D->A}.**
- $(B)^+ = \{B\}$
  $= \{B,D\}$
  $=\{ B,D,A\}$
  $=\{B,D,A,C\}$
  $=\{B,D,A,C,E\}$

Attributes Added in Closure	FD used
{B}	Triviality
{B, D}	B->D
{B, D, A}	D->A
{B, D, A, C}	AB->C
{B, D, A, C, E}	C->E

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Closure of FD EXAMPLE'S

Ex1. To find Candidate keys

- R(ABCD)
- FD: {A□ B,B□ C,C□ D}
- **Ans:**
- Closure of A means what A determines.
- Find closure of all attributes:
- A^+= {A,B,C,D} S.K
- B^+={B,C,D}
- C^+={C,D}
- D^+={D}
- AB^+={ABCD} S.K
- AC^+ = {ABCD} S.K
- $AD^+ = ABC^+ = ABD^+ = ACD^+ \cdots$ S.K
- **CK={A}**

- PRIME ATTRIBUTE:

The set of attributes makes candidate key are called prime attributes.

Here,

Prime attributes are : {A}

Non –prime: {B,C,D}

Hence, candidate key is A.

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Example

- Given Relation R(A,B,C,D,E) & FD: {A□ B, D□ E}

- $ABCDE^+$ = {A,B,C,D,E} S.K
- $ACDE^+$ = {A,B,C,D,E} S.K
- ACD^+ = {A,B,C,D,E} S.K
- How to check ACD is only the candidate key.
- Prime attributes: {A,C,D}
- Check any of the prime attribute is available in R.H.S of Functional Dependency i.e A,C & D
- No any prime attribute is present in RHS. So we can say that is the only candidate key {ACD}.

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