Chapter 8
Functional Dependencies and Normalization

(Phụ thuộc hàm và chuẩn hóa)

KHOA CÔNG NGHỆ THÔNG TIN
TRƯỜNG ĐẠI HỌC KHOA HỌC TỰ NHIÊN

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Outline

1. Design a relational database
2. Redundant Information in Tuples and Update Anomalies
3. Functional dependencies
4. Armstrong's inference rules
5. Normalization

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1. Design a relational database

CONCEPTUAL DESIGN
(THIẾT KẾ QUAN NIỆM)

↓

LOGIC DESIGN
(THIẾT KẾ LÔ-GÍC)

↓

PHYSICAL DESIGN
(THIẾT KẾ VẬT LÝ)

- To respond to information requests for specific users and applications.
- To provide the right storage for data, and data is easy to understand.
- To supports performance requirements: response time, processing time, storage space, ...

Informal Design Guidelines

- 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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Criteria for "good" base relations

- A well-designed database schema is shown by:
  - Semantics of relations and attributes are clearly defined
  - Attributes must not overlap
  - Data duplication between tuples must be reduced (redundancy of information)
  - Null value on relations is minimum.
- Duplicated data leads to:
  - Waste storage space
  - Anomalies when performing data updates
- How to verify a schema being "**good**" base relations:
  - By experience
  - By normal form

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Design steps to achieve “**good**” base relations

1. Conceptual design schema
2. Transfer the schema to a logical level
3. Identify functional dependencies and normal form
4. Normalize the schema
5. Evaluate the quality of the schema

Outline

1. Design a relational database
2. **Redundant Information in Tuples and Update Anomalies**
3. Functional dependencies
4. Armstrong's inference rules
5. Normalization

2.1. Redundant Information in Tuples

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- When redundant data happens?
  - When a piece of data can be inferred from other data, it is said the data is redundant or duplicated.

Redundancy

MAGV	TENGV	NGSINH	DCHI	MABM	TENBM	TRGBM
009	Tiên	11/02/1960	119 Cống Quỳnh, Tp HCM	5	HTTT	005
005	Tùng	20/08/1962	222 Nguyễn Văn Cừ, Tp HCM	5	HTTT	005
007	Hằng	11/3/1954	332 Nguyễn Thái Học, Tp HCM	4	MMT	008
001	Như	01/02/1967	291 Hồ Văn Huê, Tp HCM	4	MMT	008
004	Hùng	04/03/1967	95 Bà Rịa, Vũng Tàu	5	HTTT	005
003	Tâm	04/05/1957	34 Mai Thị Lự, Tp HCM	5	HTTT	005
008	Quang	01/09/1967	80 Lê Hồng Phong, Tp HCM	4	MMT	008
006	Vinh	01/01/1965	45 Trưng Vương, Hà Nội	1	CNPM	006

Redundancy: Information about **department name** and **department head** is repeated several times

2.1. Redundant Information in Tuples

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- Waste storage space

MAGV	TENGV	NGSINH	DCHI	MABM	TENBM	TRGBM
009	Tiên	11/02/1960	119 Cống Quỳnh, Tp HCM	5	HTTT	005
005	Tùng	20/08/1962	222 Nguyễn Văn Cừ, Tp HCM	5	HTTT	005
007	Hằng	11/3/1954	332 Nguyễn Thái Học, Tp HCM	4	MMT	008
001	Như	01/02/1967	291 Hồ Văn Huê, Tp HCM	4	MMT	008
004	Hùng	04/03/1967	95 Bà Rịa, Vũng Tàu	5	HTTT	005
003	Tâm	04/05/1957	34 Mai Thị Lự, Tp HCM	5	HTTT	005
008	Quang	01/09/1967	80 Lê Hồng Phong, Tp HCM	4	MMT	008
006	Vinh	01/01/1965	45 Trưng Vương, Hà Nội	1	CNPM	006

Schema 1

Calculate the storage size of each schema when adding 10 teachers for the Dept. HTTT? (Assuming the size of each attribute is 20 bytes)

MAGV	TENGV	NGSINH	DCHI	MABM
009	Tiên	11/02/1960	119 Cống Quỳnh, Tp HCM	5
005	Tùng	20/08/1962	222 Nguyễn Văn Cừ, Tp HCM	5
007	Hằng	11/3/1954	332 Nguyễn Thái Học, Tp HCM	4
001	Như	01/02/1967	291 Hồ Văn Huê, Tp HCM	4
004	Hùng	04/03/1967	95 Bà Rịa, Vũng Tàu	5
003	Tâm	04/05/1957	34 Mai Thị Lự, Tp HCM	5
008	Quang	01/09/1967	80 Lê Hồng Phong, Tp HCM	4
006	Vinh	01/01/1965	45 Trưng Vương, Hà Nội	1

MABM	TENBM	TRGBM
5	HTTT	005
5	HTTT	005
4	MMT	008
4	MMT	008
5	HTTT	005
5	HTTT	005
4	MMT	008
1	CNPM	006

Schema 2

2.2. Update Anomalies

- Insert anomaly
  - Adding 1 teacher must add dept. information or must set to Null the value for dept.-related attributes. You can't add a new dept. without any teachers in that dept.
- Update anomaly
  - When updating a dept. information, all tuples of that department must be updated or this will lead to an inconsistent data. (Ex: update TENBM: “HTTT” → “SC”)
- Delete anomaly
  - Information may be lost. What happens when deleting the teacher with code 006?

MAGV	TENGV	NGSINH	DCHI	MABM	TENBM	TRGBM
009	Tiên	11/02/1960	119 Cống Quỳnh, Tp HCM	5	HTTT	005
005	Tùng	20/08/1962	222 Nguyễn Văn Cừ, Tp HCM	5	HTTT	005
007	Hằng	11/3/1954	332 Nguyễn Thái Học, Tp HCM	4	MMT	008
001	Như	01/02/1967	291 Hồ Văn Huê, Tp HCM	4	MMT	008
004	Hùng	04/03/1967	95 Bà Rịa, Vũng Tàu	5	HTTT	005
003	Tâm	04/05/1957	34 Mai Thị Lự, Tp HCM	5	HTTT	005
008	Quang	01/09/1967	80 Lê Hồng Phong, Tp HCM	4	MMT	008
006	Vinh	01/01/1965	45 Trưng Vương, Hà Nội	1	CNPM	006

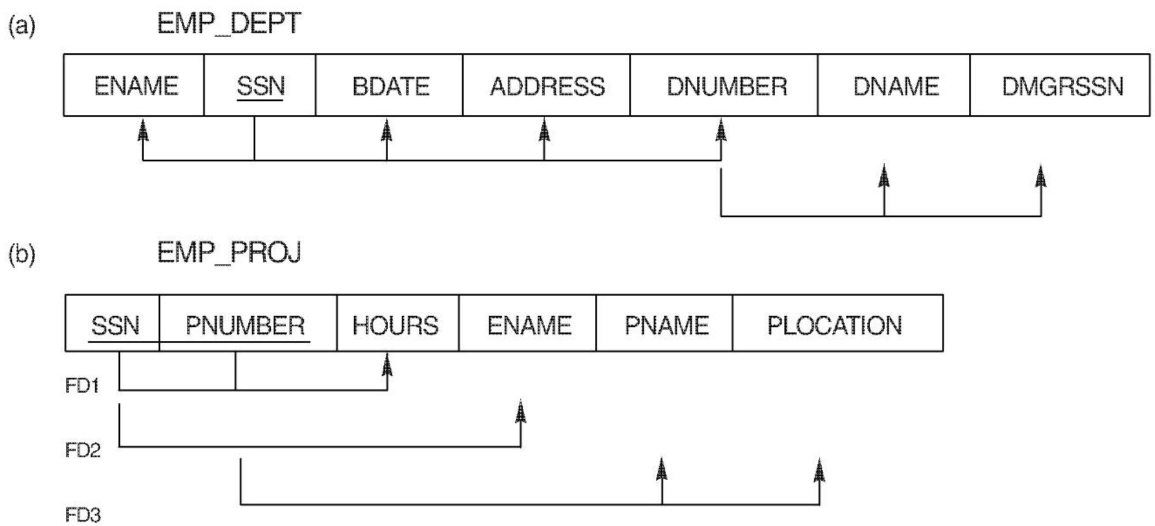
2.3. Guidelines

- **Guideline 1**:
  - Design a schema that does not suffer from the insertion, deletion and update anomalies. If there are any present, then note them so that applications can be made to take them into account.
- **Guideline 2: Null Values in Tuples**
  - 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)
  - Reasons for nulls:
    - attribute not applicable or invalid
    - attribute value unknown (may exist)
    - value known to exist, but unavailable

Quiz #1

- Identify update anomalies of the below database schema?

Figure 14.3 Two relation schemas and their functional dependencies. Both suffer from update anomalies. (a) The EMP_DEPT relation schema. (b) The EMP_PROJ relation schema.



Outline

1. Design a relational database
2. Redundant Information in Tuples and Update Anomalies
3. **Functional dependencies**
4. Armstrong's inference rules
5. Normalization

3. Functional dependencies (phụ thuộc hàm)

- Functional dependencies (FDs) are used to specify *formal measures* of the "goodness" of relational designs
- FDs and keys are used to define **normal forms** for relations
- FDs 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**

3. Functional dependencies

- Let **R** (A1, A2, …, An), **r**(R), denoted $\mathbf{R}^{+}$ = {A1, A2, …, An}.
- FD between two properties sets X, Y $\subseteq$ R^{+}:
  - Denoted: X→ Y, $\forall$r $\in$ R, t1, t2 $\in$ r, if t1[X] = t2[X] then t1[Y] = t2[Y].
  - X → Y holds if whenever two tuples have the same value for X, they *must have* the same value for Y
  - X → Y in R specifies a *constraint* on all relation instances r(R)

3. Functional dependencies

- Examples:
  - MAGV determines TENGV, NGSINH, DCHI, MABM
  - MABM determines TENBM, TRGBM

FD1: MAGV → TENGV,NGSINH,DCHI MABM
FD2: MABM → {TENBM, TRGBM}

FD2

FD1

MAGV	TENGV	NGSINH	DCHI	MABM	TENBM	TRGBM
009	Tiên	11/02/1960	119 Cống Quỳnh, Tp HCM	5	HTTT	005
005	Tùng	20/08/1962	222 Nguyễn Văn Cừ, Tp HCM	5	HTTT	005
007	Hằng	11/3/1954	332 Nguyễn Thái Học, Tp HCM	4	MMT	008
001	Như	01/02/1967	291 Hồ Văn Huê, Tp HCM	4	MMT	008
004	Hùng	04/03/1967	95 Bà Rịa, Vũng Tàu	5	HTTT	005
003	Tâm	04/05/1957	34 Mai Thị Lự, Tp HCM	5	HTTT	005
008	Quang	01/09/1967	80 Lê Hồng Phong, Tp HCM	4	MMT	008
006	Vinh	01/01/1965	45 Trưng Vương, Hà Nội	1	CNPM	006

3. Functional dependencies

- A 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]), denoted: K → R+
- FD is used to evaluate a relation database design
- FDs are derived from the real-world constraints on the attributes

3. Functional dependencies

- FD identification
  - The identification of FDs is based on the **meaning of attributes and their relationship** in Relational Schema, not on its instances
- Example:

MAGV	TENGV	NGSINH	DCHI	MABM	TENBM	TRGBM
009	Tiên	11/02/1960	119 Cống Quỳnh, Tp HCM	5	HTTT	005
005	Tùng	20/08/1962	222 Nguyễn Văn Cừ, Tp HCM	5	HTTT	005
007	Hằng	11/3/1954	332 Nguyễn Thái Học, Tp HCM	4	MMT	008
001	Như	01/02/1967	291 Hồ Văn Huê, Tp HCM	4	MMT	008
004	Hùng	04/03/1967	95 Bà Rịa, Vũng Tàu	5	HTTT	005
003	Tâm	04/05/1957	34 Mai Thị Lự, Tp HCM	5	HTTT	005
008	Quang	01/09/1967	80 Lê Hồng Phong, Tp HCM	4	MMT	008
006	Vinh	01/01/1965	45 Trưng Vương, Hà Nội	1	CNPM	006

- FDs identified based on instances?
  - MAGV → TENGV; TENGV → MAGV
- FD identified based on meaning of attributes: MAGV → TENGV

Quiz #2

Outline

1. Design a relational database
2. Redundant Information in Tuples and Update Anomalies
3. Functional dependencies
4. **Armstrong's inference rules**
5. Normalization

4. Armstrong's inference rules (Luật dẫn Armstrong)

- 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
  - **IR2**. (*Augmentation*) If X → Y, then XZ → YZ

    (Notation: XZ stands for X ∪ Z)
  - **IR3**. (*Transitive*) If X → Y and Y → Z, then X → Z
- IR1, IR2, IR3 form a *sound* and *complete* set of inference rules

4. Armstrong's inference rules

- Some **additional inference rules** that are useful:
  - **IR4.** (*Decomposition*) If X → YZ, then X → Y and X → Z
  - **IR5.** (*Union*) If X → Y and X → Z, then X → YZ
  - **IR6**. (*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)

4. Armstrong's inference rules

- **Full functional dependency**

Given $X \rightarrow Y$ is *full functional dependency* if $\forall$ $Z \subset X$, $Z \neq \emptyset$, $Z \rightarrow Y$.
Then Y is said to be fully *dependent* on X.

- Example:
  - Given **R**(A, B, C, D, E, I)
  - Set of IDs: F = { A→BCD, BCD→E, CD→EI }
  - Is BCD→E full functional dependency ?

Quiz #3

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Outline

1. Design a relational database
2. Redundant Information in Tuples and Update Anomalies
3. Functional dependencies
4. Armstrong's inference rules
5. **Normalization**

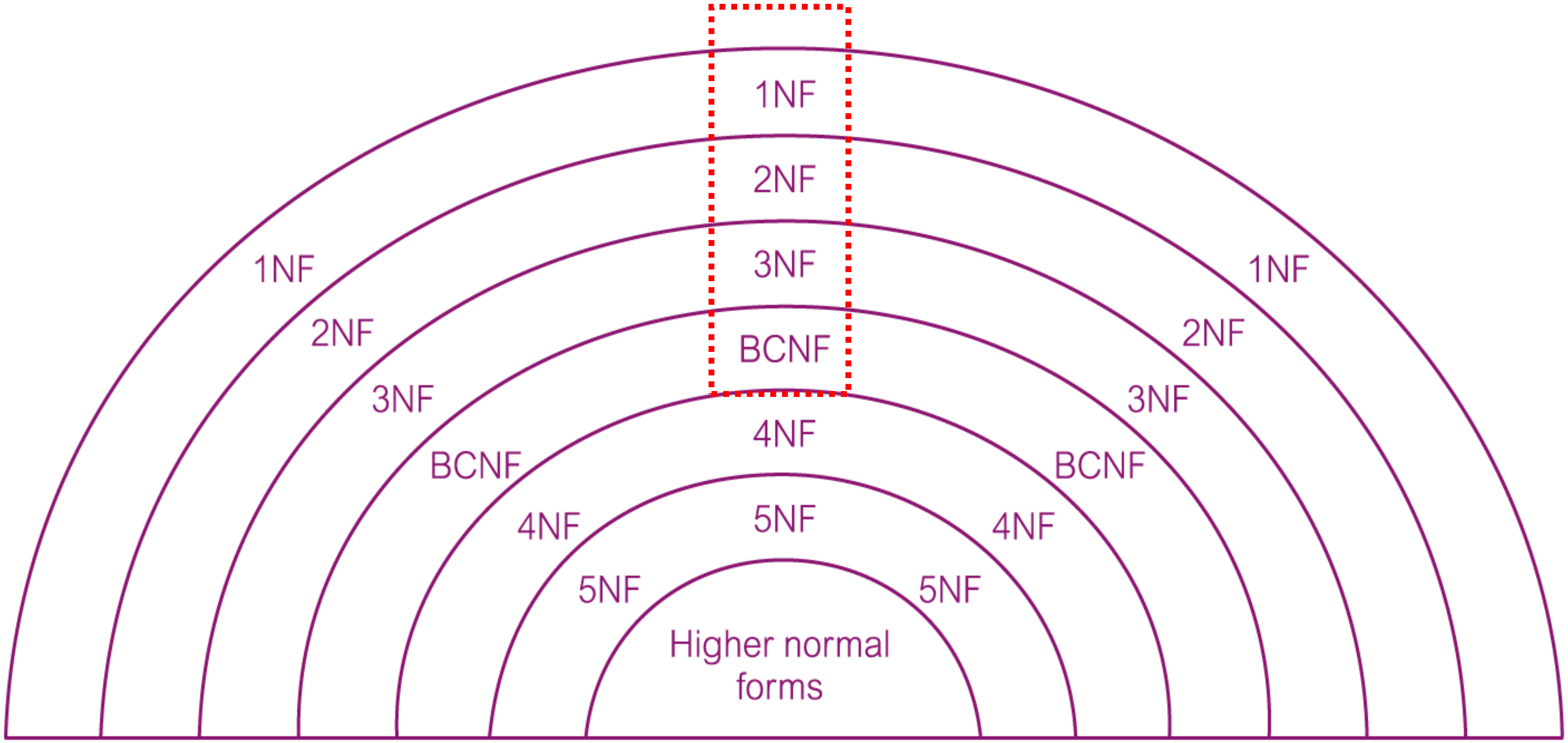
5. Normalization

- **Normalization**: The process of decomposing unsatisfactory "bad" relations by breaking up their attributes into smaller relations

- **Normal form**: Condition using keys and FDs of a relation to certify whether a relation schema is in a particular normal form

Normal forms

- Purpose: to evaluate the level of data duplication of a database schema



1^{st} Normal Form (1NF)

- Disallows composite attributes, multivalued attributes, and **nested relations**; attributes whose values *for an individual tuple* are non-atomic
- Note:
  - Every relation schema belongs to 1NF
  - 1NF has high data duplication, which causes data update anomalies
- Example: given a relation THUENHA as followings

MANT	TENNT	MANHA	DCHI_NHA	NGAYTHUE_BT	NGAYTHUE_KT	GIATHUE	MACHUNHA	TENCHUNHA
CR76	L.V.Hùng	PG4 PG16	125 Lê Văn Sỹ, Q3 432 CMT8, QTB	01/08/2012 01/09/2007	01/09/2013 01/10/2011	50tr 150tr	CO40 CO72	N.T Lan B.T.Thanh
CR56	H.V.Gia	PG4 PG16 PG36	125 Lê Văn Sỹ, Q3 432 CMT8, QTB 124 Tô Ký, Q12	01/08/2007 01//01/2012 01/01/2010	01/07/2012 01/01/2013 01/01/2014	50tr 150tr 200tr	CO40 CO72 CO20	N.T.Lan B.T.Thanh N.T.Phuong

Nested relation

Normalization relations into 1NF

- Method 1:
  - Fill in the data in the blanks with duplicate data → leading to many duplicated data on the relation.
- Method 2: nested relation into 1NF
  - Replace non-atomic values by specifying a attributes set as primary key, then splitting into a new relation → we can create two or more new relations, and this will reduce data duplication

Normalization relations into 1NF - Example

- Method 1

MANT	TENNT	MANHA	DCHI_NHA	NGAYTHUE_BT	NGAYTHUE_KT	GIATHUE	MACHUNHA	TENCHUNHA
CR76	L.V.Hùng	PG4 PG16	125 Lê Văn Sỹ, Q3 432 CMT8, QTB	01/08/2012 01/09/2007	01/09/2013 01/10/2011	50tr 150tr	CO40 CO72	N.T Lan B.T.Thanh
CR56	H.V.Gia	PG4 PG16 PG36	125 Lê Văn Sỹ, Q3 432 CMT8, QTB 124 Tô Ký, Q12	01/08/2007 01//01/2012 01/01/2010	01/07/2012 01/01/2013 01/01/2014	50tr 150tr 200tr	CO40 CO72 CO20	N.T.Lan B.T.Thanh N.T.Phuong

MANT	TENNT	MANHA	DCHI_NHA	NGAYTHUE_BT	NGAYTHUE_KT	GIATHUE	MACHUNHA	TENCHUNHA
CR76	L.V.Hùng	PG4	125 Lê Văn Sỹ, Q3	01/08/2012	01/09/2013	50tr	CO40	N.T Lan
CR76	L.V.Hùng	PG16	432 CMT8, QTB	01/09/2007	01/10/2011	150tr	CO72	B.T.Thanh
CR56	H.V.Gia	PG4	125 Lê Văn Sỹ, Q3	01/08/2007	01/07/2012	50tr	CO40	N.T.Lan
CR56	H.V.Gia	PG16	432 CMT8, QTB	01//01/2012	01/01/2013	150tr	CO72	B.T.Thanh
CR56	H.V.Gia	PG36	124 Tô Ký, Q12	01/01/2010	01/01/2014	200tr	CO20	N.T.Phuong

Normalization relations into 1NF - Example

- Method 2: split nested relations

NGUOI_THUE (<u>MANT</u>, TENNT)

MANT	TENNT
CR76	L.V.Hùng
CR56	H.V.Gia

NHA_CHO_THUE (<u>MANT, MANHA</u>, DCHI_NHA, NGAYTHUE_BT, NGAYTHUE_KT, GIATHUE, MACHUNHA, TENCHUNHA)

MANT	MANHA	DCHI_NHA	NGAYTHUE_BT	NGAYTHUE_KT	GIATHUE	MACHUNHA	TENCHUNHA
CR76	PG4	125 Lê Văn Sỹ, Q3	01/08/2012	01/09/2013	50tr	CO40	N.T Lan
CR76	PG16	432 CMT8, QTB	01/09/2007	01/10/2011	150tr	CO72	B.T.Thanh
CR56	PG4	125 Lê Văn Sỹ, Q3	01/08/2007	01/07/2012	50tr	CO40	N.T.Lan
CR56	PG16	432 CMT8, QTB	01//01/2012	01/01/2013	150tr	CO72	B.T.Thanh
CR56	PG36	124 Tô Ký, Q12	01/01/2010	01/01/2014	200tr	CO20	N.T.Phuong

Normalization relations into 1NF - Example

Figure 14.8 Normalization into 1NF. (a) Relation schema that is not in 1NF. (b) Example relation instance. (c) 1NF relation with redundancy.

(a) DEPARTMENT

DNAME	DNUMBER	DMGRSSN	DLOCATIONS

(b) DEPARTMENT

DNAME	DNUMBER	DMGRSSN	DLOCATIONS
Research	5	333445555	{Bellaire, Sugarland, Houston}
Administration	4	987654321	{Stafford}
Headquarters	1	888665555	{Houston}

(c) DEPARTMENT

DNAME	DNUMBER	DMGRSSN	DLOCATION
Research	5	333445555	Bellaire
Research	5	333445555	Sugarland
Research	5	333445555	Houston
Administration	4	987654321	Stafford
Headquarters	1	888665555	Houston

Quiz #4

2nd Normal form (2NF)

- Uses the concepts of **FDs**, **primary key**
- **(Non) Prime attribute** - attribute that is (not) member of the primary key K
- Ex: Q1(MNOPX) ; Q2(PY)
  - M,N,O are prime attributes of Q1, P is prime attribute of Q2 but is not prime attribute of Q1
- **Full dependent attribute** – Attribute A is fully dependent on X if X → A is *fully functional dependency*.

2^{nd} Normal form (2NF)

- A relation schema R is in **second normal form** if every *non-prime attribute* A in R is fully functionally dependent on the primary key
- Note:
  - R can be decomposed into 2NF relations via the process of 2NF normalization
  - All relation schemas that achieve 2NF also achieve 1NF
- Ex:

NGUOI_THUE (<u>MANT</u>, TENNT)

MANT	TENNT
CR76	L.V.Hùng
CR56	H.V.Gia

PK = {MANT}, F = {MANT → TENNT}
NGUOI_THUE achieve 2NF ?

► NGUOI_THUE: achieve 2NF

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2^{nd} Normal form (2NF) - Example

NHA_CHO_THUE (MANT, MANHA, DCHI_NHA, NGAYTHUE_BT, NGAYTHUE_KT, GIATHUE, MACHUNHA, TENCHUNHA)

MANT	MANHA	DCHI_NHA	NGAYTHUE_BT	NGAYTHUE_KT	GIATHUE	MACHUNHA	TENCHUNHA
CR76	PG4	125 Lê Văn Sỹ, Q3	01/08/2012	01/09/2013	50tr	CO40	N.T Lan
CR76	PG16	432 CMT8, QTB	01/09/2007	01/10/2011	150tr	CO72	B.T.Thanh
CR56	PG4	125 Lê Văn Sỹ, Q3	01/08/2007	01/07/2012	50tr	CO40	N.T.Lan
CR56	PG16	432 CMT8, QTB	01//01/2012	01/01/2013	150tr	CO72	B.T.Thanh
CR56	PG36	124 Tô Ký, Q12	01/01/2010	01/01/2014	200tr	CO20	N.T.Phuong

PK = {MANT, MANHA}
F = { MANHA → DCHI_NHA, GIATHUE, MACHUNHA, TENCHUNHA
NHA_CHO_THUE achieve 2NF?

► **NHA_CHO_THUE: not achieve 2NF → only achieve 1NF**

Normalizing into 2NF

- Step 1: identify **primary key** of the relation 1NF

NHA_CHO_THUE with PK = {MANT, MANHA}

- Step 2: identify FDs causing **non-prime attributes** that **are not fully dependent** on the primary key

MANHA $\rightarrow$ DCHI_NHA, GIA_THUE, MACHUNHA, TENCHUNHA

- Step 3: If it exists **non-full dependent attributes** on the primary key, remove them from the old relation and add them in a new relation
  - Remove FD: MANHA $\rightarrow$ DCHI_NHA, GIA_THUE, MACHUNHA, TENCHUNHA by adding to new relation **NHA_THUE** (<u>MANHA</u>,DCHI_NHA, GIA_THUE, MACHUNHA, TENCHUNHA).
  - Rename the relation **NHA_CHO_THUE** to: **TT_THUE_NHA** (<u>MANT,MANHA</u>, NGAYTHUE_BT, NGAYTHUE_KT)

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Normalizing into 2NF

1NF

NHA_CHO_THUE (<u>MANT, MANHA</u>, DCHI_NHA, NGAYTHUE_BT, NGAYTHUE_KT, GIATHUE, MACHUNHA, TENCHUNHA)

MANT	MANHA	DCHI_NHA	NGAYTHUE_BT	NGAYTHUE_KT	GIATHUE	MACHUNHA	TENCHUNHA
CR76	PG4	125 Lê Văn Sỹ, Q3	01/08/2012	01/09/2013	50tr	CO40	N.T Lan
CR76	PG16	432 CMT8, QTB	01/09/2007	01/10/2011	150tr	CO72	B.T.Thanh
CR56	PG4	125 Lê Văn Sỹ, Q3	01/08/2007	01/07/2012	50tr	CO40	N.T.Lan
CR56	PG16	432 CMT8, QTB	01//01/2012	01/01/2013	150tr	CO72	B.T.Thanh
CR56	PG36	124 Tô Ký, Q12	01/01/2010	01/01/2014	200tr	CO20	N.T.Phuong

NHA_THUE (<u>MANHA</u>, DCHI_NHA, GIATHUE, MACHUNHA, TENCHUNHA)

MANHA	DCHI_NHA	GIATHUE	MACHUNHA	TENCHUNHA
PG4	125 Lê Văn Sỹ, Q3	50tr	CO40	N.T Lan
PG16	432 CMT8, QTB	150tr	CO72	B.T.Thanh
PG36	124 Tô Ký, Q12	200tr	CO20	N.T.Phuong

2NF

2NF

TT_THUE_NHA (<u>MANT,MANHA</u>, NGAYTHUE_BT, NGAYTHUE_KT)

MANT	MANHA	NGAYTHUE_BT	NGAYTHUE_KT
CR76	PG4	01/08/2012	01/09/2013
CR76	PG16	01/09/2007	01/10/2011
CR56	PG4	01/08/2007	01/07/2012
CR56	PG16	01//01/2012	01/01/2013
CR56	PG36	01/01/2010	01/01/2014

Quiz #5

Normalizing into 3NF

Definition

- **Transitive functional dependency** - a FD $X \rightarrow A$ that can be derived from two FDs $X \rightarrow Y$ and $Y \rightarrow A$

  A is transitively functional dependent on **X** if four of the following conditions exist:

  - $X \rightarrow Y \in F^+$ (i)
  - $Y \rightarrow A \in F^+$ (ii)
  - $Y \rightarrow X \notin F^+$ (iii)
  - $A \notin (X \cup Y)$ (iv)

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Normalizing into 3NF

- Example:
  - Cho $F = \{MN \rightarrow OPX; NO \rightarrow M; P \rightarrow RY\}$
    - Is P transitively functional dependent on NO ($NO \rightarrow P$)?

      $NO \rightarrow M \Rightarrow NO \rightarrow MN$: satisfy (i)

      $MN \rightarrow P$: satisfy (ii)

      $MN \rightarrow O \Rightarrow MN \rightarrow NO$: not satisfy (iii)

      P is not transitively functional dependent on **NO**
    - Is R transitively functional dependent on NO ($NO \rightarrow R$)?

      $NO \rightarrow MN$ và $MN \rightarrow P \Rightarrow NO \rightarrow P$ (i)

      $P \rightarrow R$ (ii)

      $P \rightarrow NO \notin F^+$ (iii)

      $R \notin NOP$ (iv)

      R is transitively functional dependent on **NO**

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Normalizing into 3NF

- A relation schema R is in **third normal form (3NF)** if it is in 2NF *and* no non-prime attribute A in R is transitively dependent on the primary key
- Example:

NHA_THUE (<u>MANHA</u>, DCHI_NHA, GIATHUE, MACHUNHA, TENCHUNHA)

MANHA	DCHI_NHA	GIATHUE	MACHUNHA	TENCHUNHA
PG4	125 Lê Văn Sỹ, Q3	50tr	CO40	N.T Lan
PG16	432 CMT8, QTB	150tr	CO72	B.T.Thanh
PG36	124 Tô Ký, Q12	200tr	CO20	N.T.Phuong

PK = {MANHA}

F= { f1: MANHA $\rightarrow$ DCHI_NHA,GIA_THUE, MACHUNHA, TENCHUNHA

f2: MACHUNHA $\rightarrow$ TENCHUNHA }

Is NHA_THUE in 3NF?

Prove:

MANHA $\rightarrow$ MACHUNHA

MACHUNHA $\rightarrow$ TENCHUNHA

$\Rightarrow$ MANHA $\rightarrow$ TENCHUNHA (transitive)

► **NGUOI_THUE: not in 2NF, because TENCHUNHA is functional dependent on the key**

Normalizing into 3NF - Method

- Step 1: identifying the primary key of the relation that meets 2NF

  NHA_THUE: PK = {MANHA}

- Step 2:Identifying a FD that causes a non-prime attribute being transitive functional dependent on the primary key

  MACHUNHA → TENCHUNHA

- Step 3: Removing the FD by adding its attributes into a new relation

  Remove FD MACHUNHA → TENCHUNHA from the relation NHA_THUE by adding into a new relation **CHU_NHA**(MACHUNHA,TEN CHUNHA)

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Normalizing into 3NF - Method

NHA_THUE (MANHA, DCHI_NHA, GIATHUE, MACHUNHA, TENCHUNHA)

2NF

MANHA	DCHI_NHA	GIATHUE	MACHUNHA	TENCHUNHA
PG4	125 Lê Văn Sỹ, Q3	50tr	CO40	N.T Lan
PG16	432 CMT8, QTB	150tr	CO72	B.T.Thanh
PG36	124 Tô Ký, Q12	200tr	CO20	N.T.Phuong

NHA_THUE (MANHA, DCHI_NHA, GIATHUE, MACHUNHA)

MANHA	DCHI_NHA	GIATHUE	MACHUNHA
PG4	125 Lê Văn Sỹ, Q3	50tr	CO40
PG16	432 CMT8, QTB	150tr	CO72
PG36	124 Tô Ký, Q12	200tr	CO20

3NF

CHU_NHA(MACHUNHA, TENCHUNHA)

MACHUNHA	TENCHUNHA
CO40	N.T Lan
CO72	B.T.Thanh
CO20	N.T.Phuong

3NF

Normalizing into 3NF

- Notes:
  - All relation schemas that achieve 3NF also achieve 2NF.
  - The transitive functional dependency causes data duplication and the relation schema fail to achieve 3NF.
  - 3NF is not achieved due to the presence of non-prime attributes that are mutually inferable in the relation.
  - 3NF is the minimum normal form in database design

Normalizing into Boyce-Codd Normal Form (BCNF)

- A relation schema R is in **Boyce-Codd Normal Form** (**BCNF**) if whenever an FD X → A holds in R, then X is a superkey of R
- Each normal form is strictly stronger than the previous one
  - Every 2NF relation is in 1NF
  - Every 3NF relation is in 2NF
  - Every BCNF relation is in 3NF
- There exist relations that are in 3NF but not in BCNF
- The goal is to have each relation in BCNF (or 3NF)

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Normalizing into BCNF - Example

BCNF

NGUOI_THUE (MANT, TENNT)

MANT	TENNT
CR76	L.V.Hùng
CR56	H.V.Gia

BCNF

BCNF

BCNF

TT_THUE_NHA (MANT, MANHA, NGAYTHUE_BT, NGAYTHUE_KT)

MANT	MANHA	NGAYTHUE_BT	NGAYTHUE_KT
CR76	PG4	01/08/2012	01/09/2013
CR76	PG16	01/09/2007	01/10/2011
CR56	PG4	01/08/2007	01/07/2012
CR56	PG16	01//01/2012	01/01/2013
CR56	PG36	01/01/2010	01/01/2014

NHA_THUE (MANHA, DCHI_NHA, GIATHUE, MACHUNHA)

MANHA	DCHI_NHA	GIATHUE	MACHUNHA
PG4	125 Lê Văn Sỹ, Q3	50tr	CO40
PG16	432 CMT8, QTB	150tr	CO72
PG36	124 Tô Ký, Q12	200tr	CO20

CHU_NHA(MACHUNHA, TENCHUNHA)

MACHUNHA	TENCHUNHA
CO40 CO72	N.T Lan B.T.Thanh
CO20	N.T.Phuong

BCNF

Normalizing into BCNF - Example

PHONGVAN(MAUV, NGAYPV, GIOPV, MANV, MAPHG**)**

MAUV	NGAYPV	GIOPV	MANV	MAPHG
CR76	13/05/2005	10:30	SG5	G101
CR56	13/05/2005	12:00	SG5	G101
CR74	13/05/2005	12:00	SG37	G102
CR56	1/07/2005	10:30	SG5	G201

F = { FD1: MAUV, NGAYPV → GIOPV, MANV, MAPHG
FD2: MANV, NGAYPV, GIOPV → MAUV
FD3: MAPHG, NGAYPV, GIOPV → MAUV, MANV
FD4: MANV, NGAYPV → MAPHG
}

Primary key = {MAUV, NGAYPV}
Candidate keys = { (MANV, NGAYPV, GIOPV); (MAPHG, NGAYPV, GIOPV)}
⇒ **PHONGVAN: not achieve BCNF,** because FD4 having the left hand side **is not** primary key/candidate key**.**

Normalizing into BCNF

- Step 1: Identify the FD: A → B of the relation Q, where A ≠ B and A is not a superkey/key.
- Step 2: Decompose the relation Q into two relations: Q1 = {A,B}, Q2 = {the set of remaining attributes of Q } – {B}
- Step 3: Repeat the above steps for Q2 until it cannot continue.
- Step 4: The relation Q1 and the {Qi} decomposed from Q2 are the relations that achieve the BCNF.

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Normalizing into BCNF - Example

PHONGVAN(MAUV, NGAYPV, GIOPV, MANV, MAPHG) **3NF**

MAUV	NGAYPV	GIOPV	MANV	MAPHG
CR76	13/05/2005	10:30	SG5	G101
CR56	13/05/2005	12:00	SG5	G101
CR74	13/05/2005	12:00	SG37	G102
CR56	1/07/2005	10:30	SG5	G201

F = { f1: MAUV, NGAYPV → GIOPV, MANV, MAPHG
f2: MANV, NGAYPV, GIOPV → MAUV
f3: MAPHG, NGAYPV, GIOPV → MAUV, MANV
f4: MANV, NGAYPV → MAPHG
}

BCNF

NV_PHONG (MANV,NGAYPV, MAPHG)

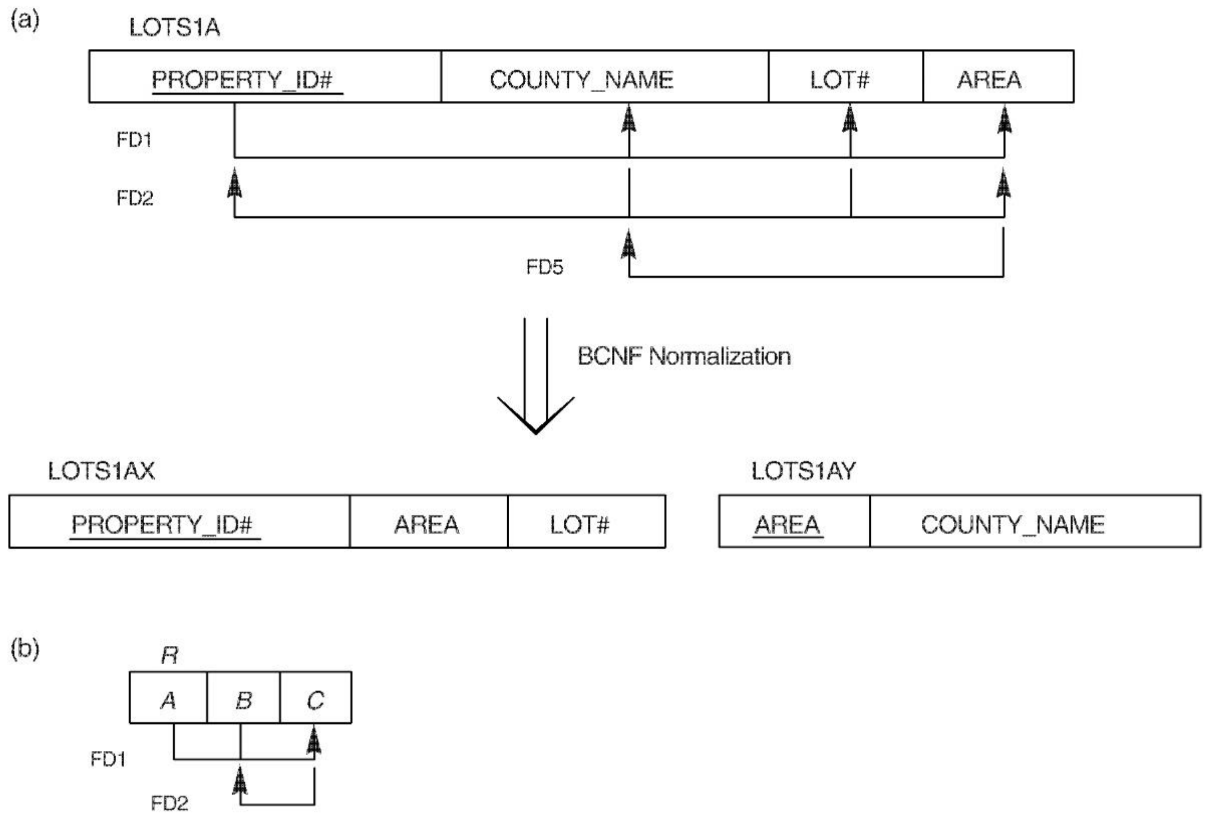
MANV	NGAYPV	MAPHG
SG5	13/05/2005	G101
~~SG5~~	~~13/05/2005~~	~~G101~~
SG37	13/05/2005	G102
SG5	1/07/2005	G201

PHONGVAN(MAUV,NGAYPV, GIOPV, MANV) **BCNF**

MAUV	NGAYPV	GIOPV	MANV
CR76	13/05/2005	10:30	SG5
CR56	13/05/2005	12:00	SG5
CR74	13/05/2005	12:00	SG37
CR56	1/07/2005	10:30	SG5

Normalizing into BCNF - Example

Figure 14.12 Boyce-Codd normal form. (a) BCNF normalization with the dependency of FD2 being "lost" in the decomposition. (b) A relation *R* in 3NF but not in BCNF.



Normalizing into BCNF - Example

- A relation TEACH that is in 3NF but not in BCNF

TEACH

Student	Course	Instructor
Narayan	Database	Mark
Smith	Database	Navathe
Smith	Operating Systems	Ammar
Smith	Theory	Schulman
Wallace	Database	Mark
Wallace	Operating Systems	Ahamad
Wong	Database	Omiecinski
Zelaya	Database	Navathe
Narayan	Operating Systems	Ammar

FDs = {Student, Course → Instructor; Instructor → Course}

Quiz #6

Given two statement S1 and S2 as follows:

- **S1**: All relation schemas with only 2 attributes achieve 1NF, 2NF, 3NF, BCNF
- **S2**: F= {AB→C, D→E, E→C} a **minimal** set of FDs G = {AB→C, D→E, AB→E, E→C}

Indicate which of the following statements is correct?

A. S1 correct, S2 wrong
B. S1 correct, S2 correct
C. S1 wrong, S2 correct
D. S1 wrong and S2 wrong
E. Not all above correct

Quiz #7

- Consider the relation R, which has attributes that hold schedules of courses and sections at a university; **R**(Course_no, Sec_no, Offering_dept, Credit_hours, Course_level, Instructor_ssn, Semester, Year, Days_hours, Room_no, No_of_students). Suppose that the following functional dependencies hold on R:

  - {Course_no} → {Offering_dept, Credit_hours, Course_level}
  - {Course_no, Sec_no, Semester, Year} → {Days_hours, Room_no, No_of_students, Instructor_ssn}
  - {Room_no, Days_hours, Semester, Year} → {Instructor_ssn, Course_no, Sec_no}

- Try to determine which sets of attributes form keys of R. How would you normalize this relation?