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Database
Lesson 9. Normalization

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Learning Map

Sequence	Title
1	Introduction to Databases
2	Relational Databases
3	Relational Algebra
4	Structured Query Language – Part 1
5	Structured Query Language – Part 2
6	Constraints and Triggers
7	Entity Relationship Model
8	Functional Dependency
9	Normalization
10	Storage - Indexing
11	Query Processing
12	Transaction Management – Part 1
13	Transaction Management – Part 2

Outline

- Introduction
- Normal Forms
- Normalization

Objectives

- Upon completion of this lesson, students will be able to:
  - Know why we need normalization in relational DB
  - Identify normal forms such as 1st NF, 2nd NF, 3rd NF
  - Know how to normalize a relational DB into 3NF

Keywords

Keyword	Description
1st Normal Form	the domain of an attribute must include only atomic (simple, indivisible) values and the value of any attribute in a tuple must be a single value from the domain of that attribute.
2nd Normal Form	A relation that is in 1NF and every non-primary-key attribute is fully functionally dependent on *any candidate key*.
3rd Normal Form	A relation that is in 1NF and 2NF and in which no non-primary-key attribute is transitively dependent on *any candidate key*.
Normalization	Normalization is the process of removing **anomalies** and **redundancies** from DB

1. Introduction

- Motivation
- Full & Partial Dependency
- Transitive Dependency

1.1. Motivation

- Designing DB: one of the most difficult tasks
- One simplest design approach is to use a big table and store all data
- But what's the problem with this?
  - Anomalies
  - Redundancies

1.1. Motivation

- Insertion Anomalies
  - PK: (student_id, subject_id)
  - We can not insert a new subject if we do not have a student assigned to it yet
  - We can not insert a null value into PK attributes

<u>student_id</u>	full_name	dob	<u>subject_id</u>	name	result
1234	David Beckham	12/21/1997	IT3090	Databases	A
1238	Theresa May	08/06/1998	IT4843	Data integration	B
1234	David Beckham	12/21/1997	IT4868	Web mining	C
1497	Tony Blair	03/01/1999	IT3090	Databases	A
1238	Theresa May	08/06/1998	IT4868	Web mining	B
1542	Margaret Thatcher	05/08/1997	IT2000	Introduction to ICT	C

1.1. Motivation

- Update anomalies
  - An instance where the same information must be updated in several different places
  - If you update the Databases subject name, you need to update in two different places (not efficient)

<u>student_id</u>	full_name	dob	<u>subject_id</u>	name	result
1234	David Beckham	12/21/1997	IT3090	Databases	A
1238	Theresa May	08/06/1998	IT4843	Data integration	B
1234	David Beckham	12/21/1997	IT4868	Web mining	C
1497	Tony Blair	03/01/1999	IT3090	Databases	A
1238	Theresa May	08/06/1998	IT4868	Web mining	B
1542	Margaret Thatcher	05/08/1997	IT2000	Introduction to ICT	C

1.1. Motivation

- Deletion Anomalies
  - Where deleting one piece of data inadvertently causes other data to be lost
  - If we delete student Margaret Thatcher, then we will lose information about subject Introduction to ICT

student_id	full_name	dob	subject_id	name	result
1234	David Beckham	12/21/1997	IT3090	Databases	A
1238	Theresa May	08/06/1998	IT4843	Data integration	B
1234	David Beckham	12/21/1997	IT4868	Web mining	C
1497	Tony Blair	03/01/1999	IT3090	Databases	A
1238	Theresa May	08/06/1998	IT4868	Web mining	B
1542	Margaret Thatcher	05/08/1997	IT2000	Introduction to ICT	C

1.1. Motivation

- Normalization is the process of removing **anomalies** and **redundancies** from DB

1.2. Full & Partial Dependency

student_id	full_name	dob	subject_id	name	result
1234	David Beckham	12/21/1997	IT3090	Databases	A
1238	Theresa May	08/06/1998	IT4843	Data integration	B
1234	David Beckham	12/21/1997	IT4868	Web mining	C
1497	Tony Blair	03/01/1999	IT3090	Databases	A
1238	Theresa May	08/06/1998	IT4868	Web mining	B
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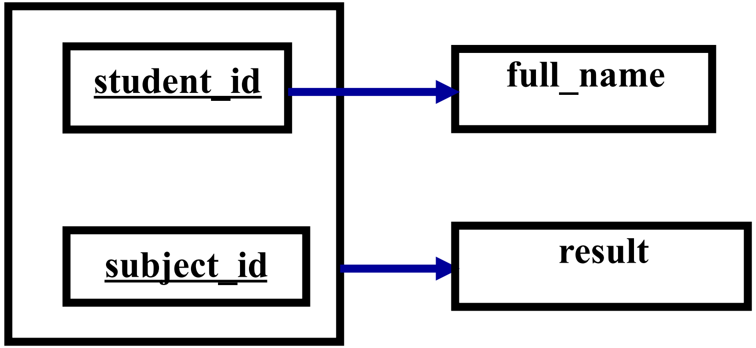
Key: (student_id, subject_id)

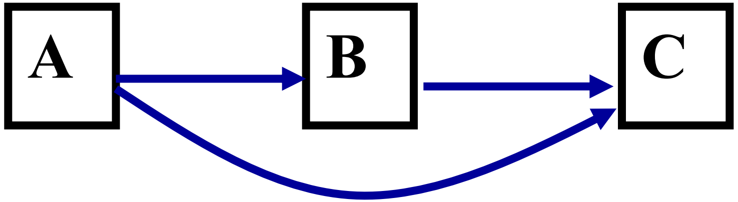
Full Key Dependency:
{student_id, subject_id} → result

Partial Key Dependency:
student_id → full_name



1.3. Transitive dependency

- If A → B and B → C
  - Attribute A must be the determinant of C.
  - Attribute A transitively determines attribute C or
  - C is transitively dependent on A



2. Normal Forms

- Introduction
- 1st Normal Form
- 2nd Normal Form
- 3rd Normal Form

2.1. Introduction

- Each form was designed to eliminate one or more of the anomalies: First NF; Second NF; Third NF
- Unnormalised Form (UNF)
  - A table that contains one or more repeating groups. I.e., its cell may contain multiple values

Multi Value
Or repeating
groups

student_id	**full_name**	**dob**	**subject_id**	**name**	**result**
1234	David Beckham	12/21/1997	IT3090, IT4868	Databases, Web mining	A, C
1238	Theresa May	08/06/1998	IT4843, IT4868	Data integration, Web mining	B, B
1497	Tony Blair	03/01/1999	IT3090	Databases	A
1542	Margaret Thatcher	05/08/1997	IT2000	Introduction to ICT	C

2.2. First Normal Form (1NF)

- A cell in a relation contains one and only one value.
  - Disallows composite attributes, multivalued attributes or nested relations

student_id	full_name	dob	subject_id	name	result
1234	David Beckham	12/21/1997	IT3090	Databases	A
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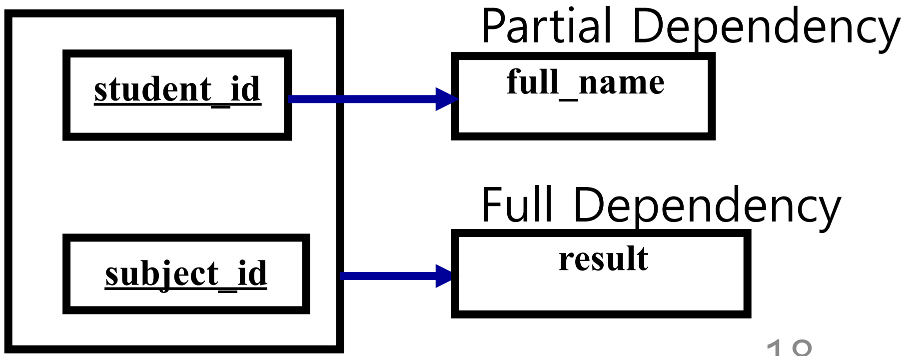
Full functional dependency

- Given R(U), F is a set of FDS in R. X, Y $\subseteq$ U. Y is fully dependent on X iff:
  - $X \rightarrow Y \subset F+$
  - $!\exists X' \subset X : X' \rightarrow Y \in F+$

2.3. Second Normal Form (2NF)

- Based on the concept of full functional dependency
- A prime attribute
  - It is an attribute that is member of some candidate key
- 2NF relation is
  - in 1NF and every non-primary-key attribute is fully functionally dependent on the primary key



2.3. Example

- Sales(sid, sname, city, item, price)
- F = {sid → (sname,city), (sid, item) → price}

- PK (sid,item)
- sname, city are partially dependent on PK
- Sales is not in 2NF

2.4. Third Normal Form (3NF)

- A relation that is
  - In 2NF and in which no non-primary-key attribute is transitively dependent on the primary key
  - I.e, all non-prime attributes are fully & directly dependent on the PK.

2.4. Example

S (sid, sname, city)

Sales(sid, item, price)

F = {sid → sname, city, sid -> iitem, price}

- S, Sales are in 3NF

ItemInfo(item, price, discount).

F = {item→price, price→discount}

- The attribute discount is not directly dependent on item
- ItemInfo is not in 3NF

3. Normalization

- Properties of relational decompositions
- An algorithm decomposes a universal relation into 3NF
- Some examples

3.1. Properties of relational decompositions

- A single universal relation schema R = {A1, A2, ..., An} that includes all the attributes of the DB
- F is a set of FDs holds on R
- Using the FDs, the algorithms decompose the universal relation schema R into a set of relation schemas D = {R1, R2, ..., Rm}; D is called a decomposition of R.

3.1. Properties of relational decompositions

- Properties:
  - Attribute preservation
    - Each attribute in *R* will appear in at least one relation schema R_i in the decomposition so that no attributes are *lost*
  - Dependency preservation
    - Each FD $X \rightarrow Y$ specified in F either appeared directly in one of the R_i in the decomposition D or could be inferred from the dependencies that appear in some R_i.
  - Lossless join
    - $r = \Pi_{R1}(r) \bowtie \Pi_{R2}(r) \bowtie \ldots \bowtie \Pi_{Rm}(r)$

3.1. Properties of relational decompositions

- An example
  - Suppose we have a relation:

    Learn(student_id, full_name, dob, subject_id, name, result)
  - We split it into two relations:

    Student(student_id, full_name, dob)

    Subject(subject_id, name)
  - This decomposition does not warrant:
    - Attribute preservation: Lost information about "result"
    - Dependency preservation condition, for instance, (student_id, subject_id) → result is loss.
    - Lossless join property, i.e., we can join these two relations

3.2. An algorithm decomposes a universal relation into 3NF

- Input: An universal relation R and a set of FDs F on the attributes of R.
  - Find a minimal cover G for F
  - For each left-hand-side X of a FD that appears in G, create a relation schema in D with attributes {X ∪ {A1} ∪ {A2} ... ∪ {Ak} }, where X → A1, X → A2, ..., X → Ak are the only dependencies in G with X as the left-hand-side (X is the key of this relation);
  - If none of the relation schemas in D contains a key of R, then create one more relation schema in D that contains attributes that form a key of R.

3.3. Some examples

- Example 1:
  - Given R = {A,B,C,D,E,F,G}, F = {A→B; ABCD→E; EF→G; ACDF→EG}
  - A minimal cover of F is G = {A→B, ACD→E, EF→G}
  - Find a minimal key: K = ACDF
  - We have R1(AB), R2(ACDE), R3(EFG)
  - Since K is not a subset of Ri, we have a new relation R4(ACDF)
  - In conclusion, we have a decomposition D = {R1, R2, R3, R4}

3.3. Some examples

- Example 2:
  - Given R(student_id, name, birthday, advisor, department, semester, course, grade)
  - F = { student_id → (name, birthday); advisor → department; (student_id, semester, course) → (grade, advisor, department)}
  - We denote like this: student_id (A), name (B), birthday (C), advisor (D), department (E), semester (F), course (G), grade (H)
  - F is rewritten as {A →BC; D →E; AFG →HDE}
  - A minimal cover of F is G = {A→B; A →C; D →E; AFG →H, AFG -> D}
  - Find a minimal key: K = AFG
  - We have R1(ABC), R2(DE), R3(AFGHD)
  - Since K is a subset of R3, we have a decomposition D = {R1, R2, R3} or {R1(student_id, name, birthday), R2(advisor, department), R3(student_id, semester, course, advisor, grade)}

- Given R(U, F), U = {A B C D E G H}
- F = { A→ CGE, B→CA, BDA→H}
- a. Find a minimal key of R
- b. Is R in 3 NF? If not, please normalize R in 3 NF

Remarks

- Motivation of normalization
- Full & Partial Dependency
- Transitive dependency
- 1NF, 2 NF, 3 NF
- Properties of relational decompositions
- An algorithm decomposes a universal relation into 3NF

Quiz

No	Question (Multiple Choice)	Answer (1,2,3,4)	Commentary
1	How many kinds of anomalies have we just studied? 1. 1 2. 2 3. 3 4. 4	3	Insert anomalies, Update anomalies, Delete anomalies
2	A relation is under the form of 3NF must satisfy: 1. A cell in a relation contains one and only one value 2. All non-primary-key attributes fully depend on the primary key 3. All non-primary-key attributes directly depend on the primary key 4. 1, 2, 3 together	4	A relation is under the form of 3NF must satisfy: - Each cell contains only an atomic value (1NF) - All non-primary-key attributes fully depend on the primary key (2NF) - All non-primary-key attributes directly depend on the primary key (3NF)
3			

Next lesson: Storage & Indexing

- Hector Garcia-Molina, Jeffrey D. Ullman, Jennifer Widom. Database Systems: The Complete Book. Pearson Prentice Hall. the 2nd edition. 2008: Chapter 7
- Nguyen Kim Anh, Nguyên lý các hệ cơ sở dữ liệu, NXB Giáo dục. 2004: Chương 7