Normalization

Learning Maps

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

Intro > Overview

☐ A : Voice and PPT Overview
☐ B : Text-based Overview
■ C : Video and PPT Overview

Opening Message	→ In this lesson, we will study the motivation of normalization in a relational DB, the definitions of Normal Forms, and the process to normalize relations to standard forms
Lesson topic	1. Introduction 2. Normal Forms 3. Normalization
Learning Goals	Upon completion of this lesson, students will be able to: 1. Know why we need normalization in relational DB 2. Identify normal forms such as 1^{st} NF, 2^{nd} NF, 3^{rd} NF 3. Know how to normalize a relational DB into 3NF

Intro > Keywords

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

Lesson > Topic 1: Introduction

- 1.1. Motivation
- 1.2. Full & Partial Dependency
- 1.3. 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

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

- 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)

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

- 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

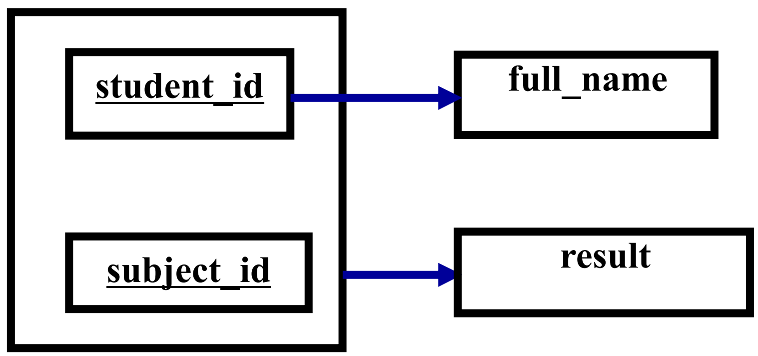
1.2. Full & Partial Dependency

<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

Key: (<u>student_id, subject_id</u>)

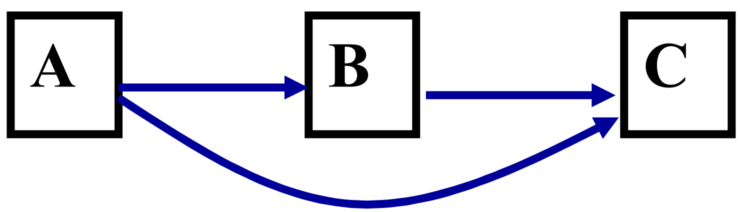
Full Key Dependency:
{student_id, subject_id} → result

Partial Key Dependency:
student_id → full_name



1.3. Transitive dependency

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



Lesson > Topic 2: Normal Forms

- 2.1. Introduction
- 2.2. 1st Normal Form
- 2.3. 2nd Normal Form
- 2.4. 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

<u>student_id</u>	**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

<u>student_id</u>	full_name	dob	<u>subject_id</u>	name	result
1234	David Beckham	12/21/1997	IT3090	Databases	A
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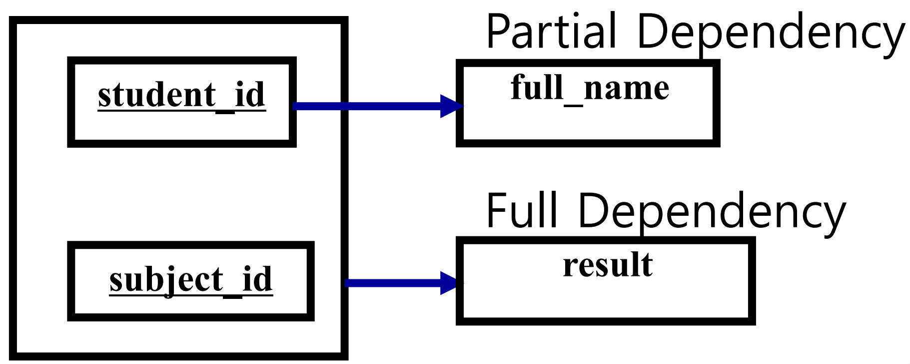
2.3. Second Normal Form (2NF)

- 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



2.4. 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.

Lesson > Topic 3: Normalization

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

3.1. Properties of relational decompositions

- A single universal relation schema $R = \{A_1, A_2, ..., A_n\}$ 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 $D = \{R_1, R_2, ..., R_m\}$; D is called a decomposition of R.

3.1. Properties of relational decompositions

- 3 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:** A 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 $\{X \cup \{A_1\} \cup \{A_2\} \ldots \cup \{A_k\}\}$, where $X \rightarrow A_1$, $X \rightarrow A_2$, ..., $X \rightarrow A_k$ are the only dependencies in G with X as the left-hand-side (X is the key of this relation);
  - Place any remaining attributes (that have not been placed in any relation) in a single relation schema to ensure the attribute preservation property.

3.2. An algorithm decomposes a universal relation into 3NF

- 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.
- Eliminate redundant relations from the resulting set of relations in the relational database schema. A relation R is considered redundant if R is a projection of another relation S in the schema; alternately, R is subsumed by S

3.3. Some examples

- Example 1:
  - Given R = {A,B,C,D,E,F,G}, F = {$A \to B$; $ABCD \to E$; $EF \to G$; $ACDF \to EG$}
  - A minimal cover of F is G = {$A \to B$, $ACD \to E$, $EF \to G$}
  - Find a minimal key: K = ACDF
  - We have R_1(AB), R_2(ACDE), R_3(EFG)
  - Since K is not a subset of R_i, we have a new relation R_4(ACDF)
  - In conclusion, we have a decomposition D = {R_1, R_2, R_3, R_4}

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}
  - Find a minimal key: K = AFG
  - We have R_1(ABC), R_2(DE), R_3(AFGH)
  - Since K is a subset of R_3, we have a decomposition D = {R_1, R_2, R_3} or {R_1(student_id, name, birthday), R_2(advisor, department), R_3(student_id, semester, course, grade)}

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 val ue 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			

→You have just learnt the following topics:
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

Next lesson:

Storage - Indexing