

Functional Dependencies and Normal Forms

Lecture 9 Sections 15.1 - 15.4

Robb T. Koether

Hampden-Sydney College

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- 1 Normal Forms
- 2 First Normal Form
- 3 Functional Dependencies
- 4 Second Normal Form
- 5 Assignment

Outline

- 1 Normal Forms
- 2 First Normal Form
- 3 Functional Dependencies
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Normal Forms

- A **normal form** is a standard form.
- The standard forms are generally easier to work with and they are more efficient.
- Nonstandard forms can be inefficient (time or space) and can be error prone.

Normal Forms

- There are several levels of normal form for databases, each one built on the preceding level.
 - First Normal Form.
 - Second Normal Form.
 - Third Normal Form.
 - Boyce-Codd Normal Form.
 - Fourth Normal Form.
 - Fifth Normal Form.

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First Normal Form

Definition (First Normal Form)

A relation is in **first normal form** (1NF) if the value of every attribute for every tuple is a single value (atomic).

- This rules out lists of values or sets of values.

First Normal Form

Not in First Normal Form

order_no	cat_no	dept	sales_person	quant	cust_no	cust_name
222	1234	hardware	John Wilson	2	3333	Joe Smith
	3456			2		
444	4567	lumber	Tim Gramm	2	4444	Sue Taylor
555	5678	garden	David Simon	3	3333	Joe Smith
	6789			1		
777	4567	lumber	Tim Gramm	2	7777	Bob Sponge
888	1234	hardware	Ben Sherman	1	4444	Sue Taylor

- In the `orders` table, one order may include multiple items.
- Nevertheless, we make a separate tuple for each item.

Example – 1NF Normalized Table

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order_no	cat_no	dept	sales_person	quant	cust_no	cust_name
222	1234	hardware	John Wilson	2	3333	Joe Smith
222	3456	hardware	John Wilson	2	3333	Joe Smith
444	4567	lumber	Tim Gramm	2	4444	Sue Taylor
555	5678	garden	David Simon	3	3333	Joe Smith
555	6789	garden	David Simon	1	3333	Joe Smith
777	4567	lumber	Tim Gramm	2	7777	Bob Sponge
888	1234	hardware	Ben Sherman	1	4444	Sue Taylor

- To 1NF-normalize the table, make a separate tuple for each value.

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Functional Dependencies

Definition (Functional Dependency)

For any tuple t and for any set of attributes A , let $t[A]$ represent the values of t on the attributes in A . Let X and Y be two sets of attributes. Then Y is **functionally dependent** on X , denoted $X \rightarrow Y$, if

$$t_1[X] = t_2[X] \Rightarrow t_1[Y] = t_2[Y].$$

The relation $X \rightarrow Y$ is a **functional dependency**.

- This means that if two tuples have the same values for the attributes in X , then they must also have the same values for the attributes in Y .

Example

- Consider a relation `emp_proj_works` with the attributes
 - `ssn` – Social Security number
 - `lname` – Last name
 - `proj` – Project number
 - `proj_name` – Project name
 - `dept` – Department of the project
 - `hours` – Number of hours employee worked on project.
- Using the **semantics** of the situation, list all functional dependencies.

Example

- The following are a few functional dependencies in the `company` database.

`[ssn ] → [lname]`

`[ssn, dept ] → [lname]`

`[ssn ] → [lname, dept, proj, proj_name]`

`[proj ] → [proj_name]`

`[proj ] → [dept]`

`[proj ] → [proj_name, dept]`

`[ssn, proj ] → [hours]`

- List all functional dependencies in the earlier example.

Superkeys and Keys

Definition (Superkey)

Let A be the set of all attributes in a relation R . Then a set $S \subseteq A$ is a **superkey** of R if $S \rightarrow A$.

Definition (Candidate Key, Key)

A collection of attributes K is a **candidate key** of a relation R if K is a superkey of R , but no proper subset of K is a superkey of R . A candidate key is also called a **key**.

Definition (Primary Key)

A **primary key** of a relation is an arbitrarily selected candidate key.

Superkeys and Keys

- A key is a “minimal” superkey in the sense that if we remove any attribute from it, then it is no longer a superkey.
- What are the superkeys of the relation `emp_proj_works`?
- What are the candidate keys?
- What is the primary key? (our choice)

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Full Functional Dependency

Definition (Full Functional Dependency)

A functional dependency $X \rightarrow Y$ is **full** if removal of any of the attributes from X renders it no longer a functional dependency. Otherwise, the functional dependency is **partial**.

- A full functional dependency is minimal for the set Y as a whole, but it may not be minimal for each attribute in Y .
- This is similar to the definition of a key, but applied only to the set Y .
- If the primary key is a single attribute, then there can be no partial dependencies.

Primary Key

Definition (Prime Attribute)

A **prime attribute** of a relation R is an attribute that is a member of some key of R . All other attributes are **non-prime**.

- List the prime attributes in the previous example.
- List the non-prime attributes in the previous example.

Second Normal Form

Definition (Second Normal Form)

A relation is in **second normal form** (2NF) if every nonprime attribute A is fully functionally dependent on the primary key.

- The idea is to avoid any subsets of the primary key that could serve as a primary key for some of the nonprime attributes.

Example

Example

<i>order_no</i>	<i>cat_no</i>	<i>dept</i>	<i>sales_person</i>	<i>quant</i>	<i>cust_no</i>	<i>cust_name</i>
222	1234	hardware	John Wilson	2	3333	Joe Smith
222	3456	hardware	John Wilson	2	3333	Joe Smith
444	4567	lumber	Tim Gramm	2	4444	Sue Taylor
555	5678	garden	David Simon	3	3333	Joe Smith
555	6789	garden	David Simon	1	3333	Joe Smith
777	4567	lumber	Tim Gramm	2	7777	Bob Sponge
888	1234	hardware	Ben Sherman	1	4444	Sue Taylor

- Show that the relation is not in 2NF.

2NF Normalization

- To put a relation into 2NF, move the nonprime keys that are not fully functionally dependent on the primary key to a separate table along with that part of the primary key on which they are fully functionally dependent.

Example – 2NF Normalized Tables

Example – 2NF Normalized Tables

<i>order_no</i>	<i>cat_no</i>	<i>quant</i>
222	1234	2
222	3456	2
444	4567	2
555	5678	3
555	6789	1
777	4567	2
888	1234	1

Table 1

<i>order_no</i>	<i>dept</i>	<i>sales_person</i>
222	hardware	John Wilson
444	lumber	Tim Gramm
555	garden	David Simon
777	lumber	Tim Gramm
888	hardware	Ben Sherman

Table 2

<i>order_no</i>	<i>cust_no</i>	<i>cust_name</i>
222	3333	Joe Smith
444	4444	Sue Taylor
555	3333	Joe Smith
777	7777	Bob Sponge
888	4444	Sue Taylor

Table 3

- The three tables above are in 2NF.

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Assignment

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- Read Sections 15.1 - 15.4.