Boyce-Codd Normal Forms

Lecture 31

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Outline

Third Normal Form

Definition (Transitive Dependence)

A set of attributes Z is transitively dependent on a set of attributes X if there exists a set of attributes Y such that $X \to Y$ and $Y \to Z$.

Definition (Third Normal Form)

A relation R is in third normal form (3NF) if it is in 2NF and there is no nonprime attribute of R that is transitively dependent on any key of R.

- 3NF is violated if there is a nonprime attribute A that depends on something less than a key.

Example

Example

order_no	sales_person	cust_no	cust_name
222	John Wilson	3333	Joe Smith
444	Tim Gramm	4444	Sue Taylor
555	David Simon	3333	Joe Smith
777	Tim Gramm	7777	Bob Sponge
888	Ben Sherman	4444	Sue Taylor

Table 3

- Table 3 is in 2NF, but it is not in 3NF because

$$[\text{order\_no}] \rightarrow [\text{cust\_no}] \rightarrow [\text{cust\_name}].$$

3NF Normalization

- To put a relation into 3NF, for each set of transitive function dependencies $X \to Y \to Z$, make two tables, one for $X \to Y$ and another for $Y \to Z$.

Example – 3NF Normalized Tables

Example – 3NF Normalized Table

order_no	*cat_no*	quant
222	1234	2
222	3456	2
444	4567	2
555	5678	3
555	6789	1
777	4567	2
888	1234	1

Table 1

cat_no	*dept*
1234	hardware
3456	hardware
4567	lumber
5678	garden
6789	garden

Table 2

order_no	sales_person	cust_no
222	John Wilson	3333
444	Tim Gramm	4444
555	David Simon	3333
777	Tim Gramm	7777
888	Ben Sherman	4444

Table 4

cust_no	cust_name
3333	Joe Smith
4444	Sue Taylor
7777	Bob Sponge

Table 5

- The four tables above are in 3NF.

Outline

Example

Example (Second and Third Normal Form)

- Table 1 contains
  - Course ID
  - Course name
  - Tutor ID
  - Tutor name
- Table 2 contains
  - Course ID
  - Student ID
  - Student name
  - Date of birth
  - Number of absences
- Find the functional dependencies, candidate keys, and prime keys and put into 2NF and 3NF.

Outline

Boyce-Codd Normal Form

Definition (Boyce-Codd Normal Form)

A relation R is in Boyce-Codd normal form (BCNF) if for every attribute A and for every nontrivial functional dependency $X \to A$, X is a superkey of R.

- That is, no attribute (prime or nonprime) depends on anything less than a superkey.

Example

Example

Bldg	Room	Start	End	Prof
Bagby	111	9:30	10:20	Valente
Bagby	020	10:30	11:20	Koether
Bagby	020	12:30	1:20	Koether
Morton	120	12:30	1:20	Marion
Morton	112	10:30	11:50	Booker
Gilmer	025	9:30	10:50	Thurman
Gilmer	012	9:30	10:20	Bloom

- What are the candidate keys?

Example

Example

Bldg	Room	Start	End	Prof
Bagby	111	9:30	10:20	Valente
Bagby	020	10:30	11:20	Koether
Bagby	020	12:30	1:20	Koether
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Gilmer	012	9:30	10:20	Bloom

- What are the candidate keys?
- Semantics: Each professor teaches in only one building.

Example

- The candidate keys are
  - (Bldg, Room, Start)
  - (Bldg, Room, End)
  - (Start, Prof)
  - (End, Prof)
- Verify that this relation is in 3NF.

Example

- Prof $\rightarrow$ Bldg, but Prof is not a superkey.
- What to do?

BCNF Normalization

Example

Room	*Start*	End	*Prof*
111	9:30	10:20	Valente
020	10:30	11:20	Koether
020	12:30	1:20	Koether
120	12:30	1:20	Marion
112	10:30	11:20	Booker
025	9:30	10:20	Thurman
012	9:30	10:20	Bloom

Bldg	*Prof*
Bagby	Valente
Bagby	Koether
Morton	Marion
Morton	Booker
Gilmer	Thurman
Gilmer	Bloom

- To put the relation in BCNF, create a separate table based on the functional dependency $X \to A$ that violates BCNF.
- In this case, remove (Prof, Bldg) to a separate table.

Exercises

Example (Exercises)

For each of the following sets of functional dependencies, transform $R(A, B, C, D)$ into BCNF, if it is not already in BCNF.

1. $AB \to C$, $C \to D$, $D \to A$.
2. $B \to C$, $B \to D$.
3. $AB \to C$, $BC \to D$, $CD \to A$, $AD \to B$.
4. $A \to B$, $B \to C$, $C \to D$, $D \to A$.

Exercises

Example (Exercises)

- A relation has three attributes: A: pizza_id, B: topping, C: topping_type.
- The semantics:
  - There are several topping types (e.g., meat, cheese, vegetable).
  - There are several toppings of each type (e.g., pepperoni, sausage).
  - A pizza may have only one topping of each type.
- List the dependencies.
- List the candidate keys and choose a primary key.
- Is this relation in 3NF?
- Is it in BCNF?