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1. Consider the following functional dependencies:

$$AB \rightarrow CD$$

$$AF \rightarrow D$$

$$DE \rightarrow F$$

$$C \rightarrow G$$

$$F \rightarrow E$$

$$G \rightarrow A$$

Find $\{CF\}^*$, $\{BG\}^+$, $\{AF\}^+$, $\{AB\}^+$

$$\begin{aligned}\rightarrow \{CF\}^* &= \{C, F\} \\&= \{C, F, G\} \quad (\text{using } C \rightarrow G) \\&= \{C, F, E, G\} \quad (\text{using } F \rightarrow E) \\&= \{A, C, E, F, G\} \quad (\text{using } G \rightarrow A) \\&= \{A, C, D, E, F, G\} \quad (\text{using } AF \rightarrow D)\end{aligned}$$

$$\begin{aligned}\{BG\}^+ &= \{B, G\} \\&= \{A, B, G\} \quad (\text{using } G \rightarrow A) \\&= \{A, B, C, D, G\} \quad (\text{using } AB \rightarrow CD)\end{aligned}$$

$$\begin{aligned}\{AF\}^+ &= \{A, F\} \\&= \{A, E, F\} \quad (\text{using } F \rightarrow E) \\&= \{A, D, E, F\} \quad (\text{using } AF \rightarrow D)\end{aligned}$$

$$\begin{aligned}\{AB\}^+ &= \{A, B\} \\&= \{A, B, C, D\} \quad (\text{using } AB \rightarrow CD) \\&= \{A, B, C, D, G\} \quad (\text{using } C \rightarrow G)\end{aligned}$$

2. Let $R = (A, B, C, D, E)$ be a relation scheme with the following dependencies:

$$AB \rightarrow C$$

$$C \rightarrow D$$

$$B \rightarrow E$$

Determine the total number of candidate keys.

- The dependencies we have AB, B

$$\begin{aligned} \text{Taking, } \{AB\}^+ &= \{A, B\} \\ &= \{A, B, C\} \quad (\text{using } AB \rightarrow C) \\ &= \{A, B, C, D\} \quad (\text{using } C \rightarrow D) \\ &= \{A, B, C, D, E\} \quad (\text{using } B \rightarrow E) \end{aligned}$$

Here, CE is the only candidate key.

3. Given $R \{ABCD\}$ and a set F of functional dependencies on R given as $F = \{AB \rightarrow C, AB \rightarrow D, C \rightarrow A, D \rightarrow B\}$. Find any two candidate keys of R . Show each step. In what normal form is R ? Justify.

- Estimate attributes are those attributes which are present only on the left side of the functional dependency and essential attribute $= \{A, B\}$

$$\begin{aligned} \{AB\}^+ &= \{A, B\} \\ &= \{A, B, C\} \quad (\text{using } AB \rightarrow C) \\ &= \{A, B, C, D\} \quad (\text{using } AB \rightarrow D) \end{aligned}$$

So, AB is a candidate key and it is able to determine all non-essential attributes.

Now,

$$\begin{aligned} \{CD\}^+ &= \{C, D\} \\ &= \{A, C, D\} \quad (\text{using } C \rightarrow A) \\ &= \{A, B, C, D\} \quad (\text{using } D \rightarrow B) \end{aligned}$$

So, CD also acts as a candidate key. Hence $\{AB\}$ and $\{CD\}$ are two candidate keys for R .

Also, R is in 3 normal forms.

4. Consider the relation schema $R = \{H, D, X, Y, Z\}$ and the functional dependencies $X \rightarrow YZ$, $DX \rightarrow W$, $Y \rightarrow H$. Find the closure F^+ of FD's.

$$\Rightarrow \{X\}^+ = \{X\}$$

$$= \{X, Y, Z\} \quad (\text{using } X \rightarrow YZ)$$

$$= \{H, X, Y, Z\} \quad (\text{using } Y \rightarrow H)$$

$$\{DX\}^+ = \{DX\}$$

$$= \{D, X, Y, Z\} \quad (\text{using } X \rightarrow YZ)$$

$$= \{D, W, X, Y, Z\} \quad (\text{using } DX \rightarrow W)$$

$$= \{D, H, W, X, Y, Z\} \quad (\text{using } Y \rightarrow H)$$

$$\{Y\}^+ = \{Y\}$$

$$= \{H, Y\} \quad (\text{using } Y \rightarrow H)$$

$\therefore DX$ works as a candidate key.

5. Consider the relation schema $R = \{A, B, C, D, E\}$ and the set of functional dependencies: $AD \rightarrow BE$, $CD \rightarrow E$, $B \rightarrow AE$, $AE \rightarrow C$, $C \rightarrow D$. List all of the candidate keys for R .

$$\Rightarrow \{AD\}^+ = \{A, D\}$$

$$= \{A, B, D, E\} \quad (\text{using } AD \rightarrow BE)$$

$$= \{A, B, C, D, E\} \quad (\text{using } AE \rightarrow C)$$

$\therefore AD$ is a candidate key.

$$\{CD\}^+ = \{C, D\}$$

$$= \{C, D, E\} \quad (\text{using } CD \rightarrow E)$$

$\therefore CD$ is not a candidate key.

$$\{B\}^+ = \{B\}$$

$$= \{A, B, E\} \quad (\text{using } B \rightarrow AE)$$

$$= \{A, B, C, E\} \quad (\text{using } AE \rightarrow C)$$

$$= \{A, B, C, D, E\} \quad (\text{using } C \rightarrow D)$$

$\therefore B$ is a candidate key.

$$\begin{aligned}
 \{AE\}^+ &= \{A, E\} \\
 &= \{A, C, E\} \quad (\because AE \rightarrow C) \\
 &= \{A, C, D, E\} \quad (\because C \rightarrow D) \\
 &= \{A, B, C, D, E\} \quad (\because AD \rightarrow BE) \\
 \therefore AE \text{ is a candidate key}
 \end{aligned}$$

$$\begin{aligned}
 \{C\}^+ &= \{C\} \\
 &= \{C, D\} \quad (\because C \rightarrow D) \\
 &= \{C, D, E\} \quad (\because CD \rightarrow E) \\
 \therefore C \text{ is not a candidate key}
 \end{aligned}$$

$\therefore AD, B$ and AE are the candidate keys.

6. Suppose you are given a relation $R(A, B, C, D)$. For each of the following sets of FDs, assuming they are the only dependencies that hold for R , identify the candidate key(s) for R .
1. $B \rightarrow C$, $D \rightarrow A$
 2. $A \rightarrow BC$, $C \rightarrow AD$
 3. $A \rightarrow B$, $B \rightarrow C$, $C \rightarrow D$

\Rightarrow (i) Essential Attributes = B, D

$$\begin{aligned}
 \text{So, } \{BD\}^+ &= \{B, D\} \\
 &= \{A, B, D\} \quad (\because D \rightarrow A) \\
 &= \{A, B, C, D\} \quad (\because B \rightarrow C) \\
 \therefore BD \text{ is candidate for } R(A, B, C, D)
 \end{aligned}$$

(ii) No essential keys here. Testing for multiple candidate keys,

$$\begin{aligned}
 \{A\}^+ &= \{A\} \\
 &= \{A, B, C\} \quad (\because A \rightarrow BC) \\
 &= \{A, B, C, D\} \quad (\because C \rightarrow AD)
 \end{aligned}$$

$$\begin{aligned}
 \{C\}^+ &= \{C\} \\
 &= \{A, C, D\} \quad (\because C \rightarrow AD) \\
 &= \{A, B, C, D\} \quad (\because A \rightarrow BC)
 \end{aligned}$$

$\therefore A$ and C are candidate keys for $R(A, B, C, D)$

(iii) Here, Essential Key is A.
So,

$$\begin{aligned}\{A^+\} &= \{A\} \\&= \{A, B\} \quad (\because A \rightarrow B) \\&= \{A, B, C\} \quad (\because B \rightarrow C) \\&= \{A, B, C, D\} \quad (\because C \rightarrow D)\end{aligned}$$

∴ A is the candidate key for R(A, B, C, D)