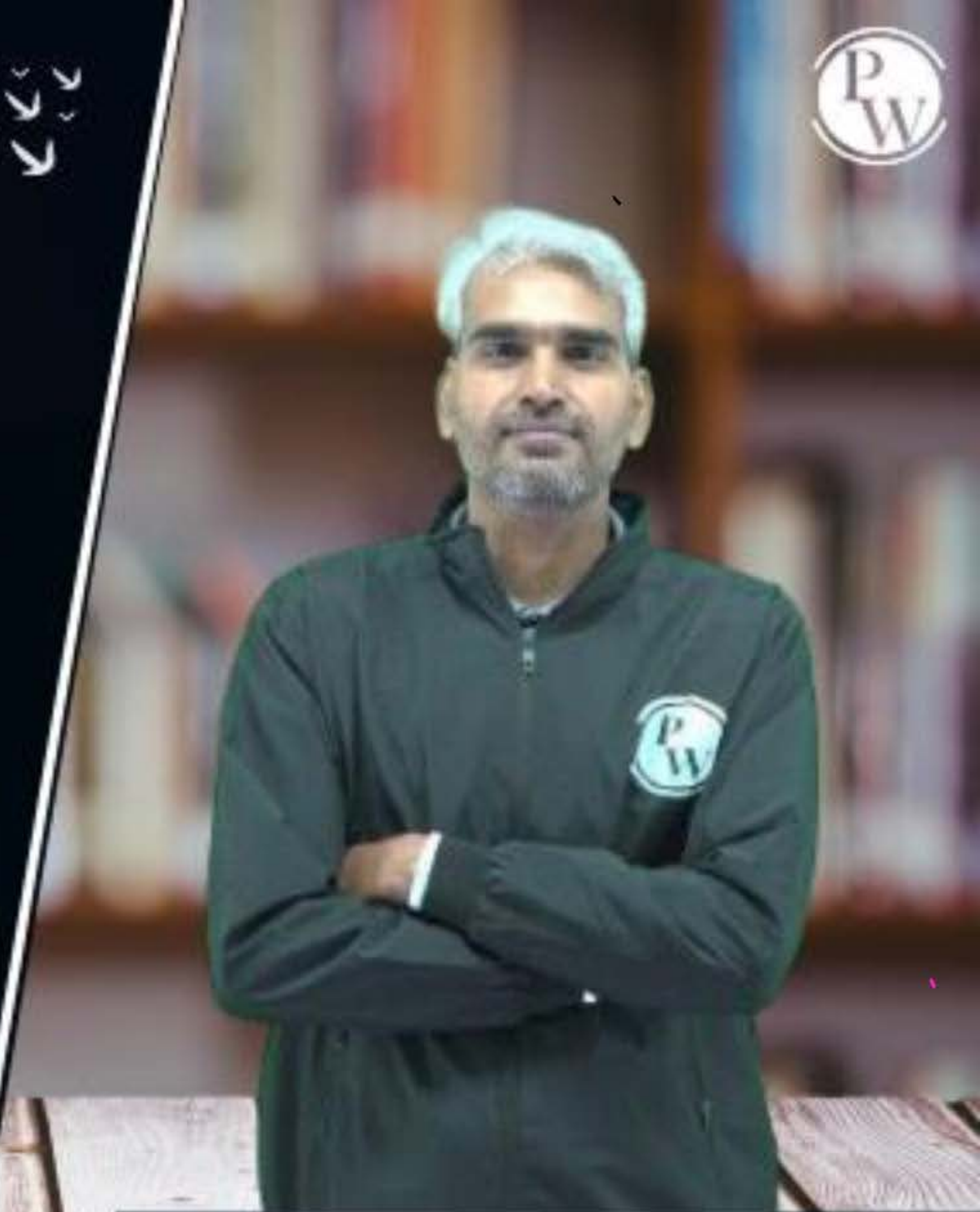
Computer Science & IT

Database Management System

Relational Model & Normal Forms

Lecture No. 11



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Recap

Topic Normal forms

Topic Decomposition of relation up to BCNF

Topics to be Covered

- **Topic** Decomposition of relation up to BCNF
- **Topic** Multi-valued dependency and 4NF

#e.g. Given R(ABCDEF) and

$F = \{AB \to CD, D \to A, C \to E, B \to F\}$

Find the normal form of the relation.

CK = (AB), (DB)

Prime Attribute = {A, B, D}

Non-prime attributes = {C, E, F}

$\underbrace{AB}_{S.K} \to CD$ ∴ Allowed up to BCNF

$C \to E$

NPA → NPA

"Type-3"

Allowed in 2NF but not allowed in 3NF

$\underbrace{D}_{\text{Proper subset of one C.K}} \to \underbrace{A}_{\text{Proper subset of another C.K}}$

"Type-4" FD

Allowed up to 3NF but not allowed in BCNF

$\underbrace{B}_{PSCK} \to \underbrace{F}_{NPA}$

"Type-1"

Allowed in 1NF

Not allowed in 2NF

#e.g. Given R(ABCDEF) and

$F = \{AB \to CD, D \to A, C \to E, B \to F\}$

Find the normal form of the relation.

CK = (AB), (DB)

Prime Attribute = {A, B, D}

Non-prime attributes = {C, E, F}

FD	Highest Normal form satisfied by FD
$AB \to CD$	BCNF
$D \to A$	3NF
$C \to E$	2NF
$B \to F$	1NF

Least of the highest normal form satisfied by any of its FD is "1NF"

$\therefore$ Normal form of relation is '1NF'

Normal form of a relation will be the least of highest normal form satisfied by any of its FD.

#e.g. Given R(ABCDE) and F={AB→C, C→D, B→E }

CK = (AB)

N.P.A. = {C, D, E}

Find the normal form of the relation, and if relation is not already in BCNF then decompose the relation up to BCNF.

$$F: \begin{cases} \underset{S.K}{AB} \longrightarrow C & (BCNF) \\ \underset{NPA}{C} \xrightarrow[\text{Type3}]{} \underset{NPA}{D} & (2NF) \\ \underset{PSCK}{B} \xrightarrow[\text{Type 1}]{} \underset{NPA}{E} & (1NF) \end{cases}$$

∴ Normal form of relation is 1NF

$F = \{AB \rightarrow C,\ C \rightarrow D,\ B \rightarrow E\}$

R(ABCDE) is not in 2NF because of $B \rightarrow E$

$\therefore$ Decompose w.r.t. $B \rightarrow E$

$(BE)^+ = \{B, E\}$

added to make the decomposition lossless.

BCNF

$R_1(BE)$

$F_1 = \{\underbrace{B}_{S.K} \longrightarrow E$ (BCNF)$\}$

$Ck = B$

2NF

$R_2(ABCD)$

$F_2 = \{\underbrace{AB}_{SK} \longrightarrow C$ (BCNF)

$\overset{NPA}{C} \longrightarrow \overset{NPA}{D}$ (2NF$\}$

$Ck = AB$

Overall NF of database is 2NF + Lossless + Dep. preserving

already in BCNF

Not in 3NF because of $C \rightarrow D$

$\therefore$ Decompose w.r.t $C \rightarrow D$

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

for lossless

BCNF

$R_1(BE)$

$F_1 = \{\underbrace{B}_{S.K} \longrightarrow E$ (BCNF)$\}$

$Ck = B$

BCNF

$R_3(CD)$

$F_3 = \{\underbrace{C}_{SK} \longrightarrow D$ BCNF$\}$

$Ck = C$

BCNF

$R_4(ABC)$

$F_4 = \{\underbrace{AB}_{SK} \longrightarrow C$ BCNF$\}$

$Ck = AB$

3NF + BCNF + lossless Join + Dep. preserving

$$F = \{AB \to C,\ C \to D,\ B \to E\}$$

$$\begin{tikzcd}
 & R(A\ B\ C\ D\ E) \arrow[dl] \arrow[d] \arrow[dr] & \\
R_1(BE) & R_2(CD) & R_3(ABC)
\end{tikzcd}$$

$F_1 = \{B \to E\}$

$F_2 = \{C \to D\}$

$F_3 = \{AB \to C\}$

#e.g. Given R(ABCDEF) and F={A→BCDEF, BC→ADEF, D→E , E→F}

Find the normal form of the relation, and if relation is not already in BCNF then decompose the relation up to BCNF.

CK = {A} & (BC)

A → BCDEF (BCNF)

BC → ADEF (BCNF)

D → E (2NF)

E → F (2NF)

R(ABCDEF)

Decompose w.r.t. $D \rightarrow E$

$(DE)^+ = \{D, E, F\}$

for lossless

$R_1(DEF)$

$F_1 = \left\{ \begin{array}{l} \underset{SK}{D} \rightarrow E \text{ (BCNF)} \\ \overset{NPA}{E} \rightarrow \overset{NPA}{F} \text{ (2NF)} \end{array} \right\}$

$CK = D$

$R_2(ABCD)$

$F_2 = \left\{ \begin{array}{l} A \rightarrow BCD \text{ (BCNF)} \\ BC \rightarrow AD \text{ (BCNF)} \end{array} \right\}$

$CK = A, (BC)$

2NF + Lossless + Dep. preserving

Not in 3NF because of $E \rightarrow F$

∴ Decompose w.r.t. $E \rightarrow F$

$\{EF\}^+ = \{E, F\}$

for lossless

$R_3(EF)$

$F_3 = \{E \rightarrow F \text{ (BCNF)}\}$

$CK = E$

$R_4(DE)$

$F_4 = \{D \rightarrow E \text{ (BCNF)}\}$

$CK = D$

3NF + BCNF + lossless + Dep preserving

#e.g. Given R(ABCD) and F={AB→C, BC→D}

Find the normal form of the relation, and if relation is not already in BCNF then decompose the relation up to BCNF.

CK = (AB)

$\underbrace{AB}_{S.K} \longrightarrow C$ (BCNF)

$BC \longrightarrow D$ (2NF)

(PSCK + NPA) ⟶ (NPA)

"Type 2"

R(ABCD)

Decompose w.r.t. $BC \to D$

$(BCD)^+ = \{B, C, D\}$

for lossless

$R_1(BCD)$

$F_1: \{ \underset{SK}{BC} \to D$ (BCNF) }

CK = (BC)

$R_2(A\,BC)$

$F_2: \{ \underbrace{AB}_{SK} \to C$ (BCNF) }

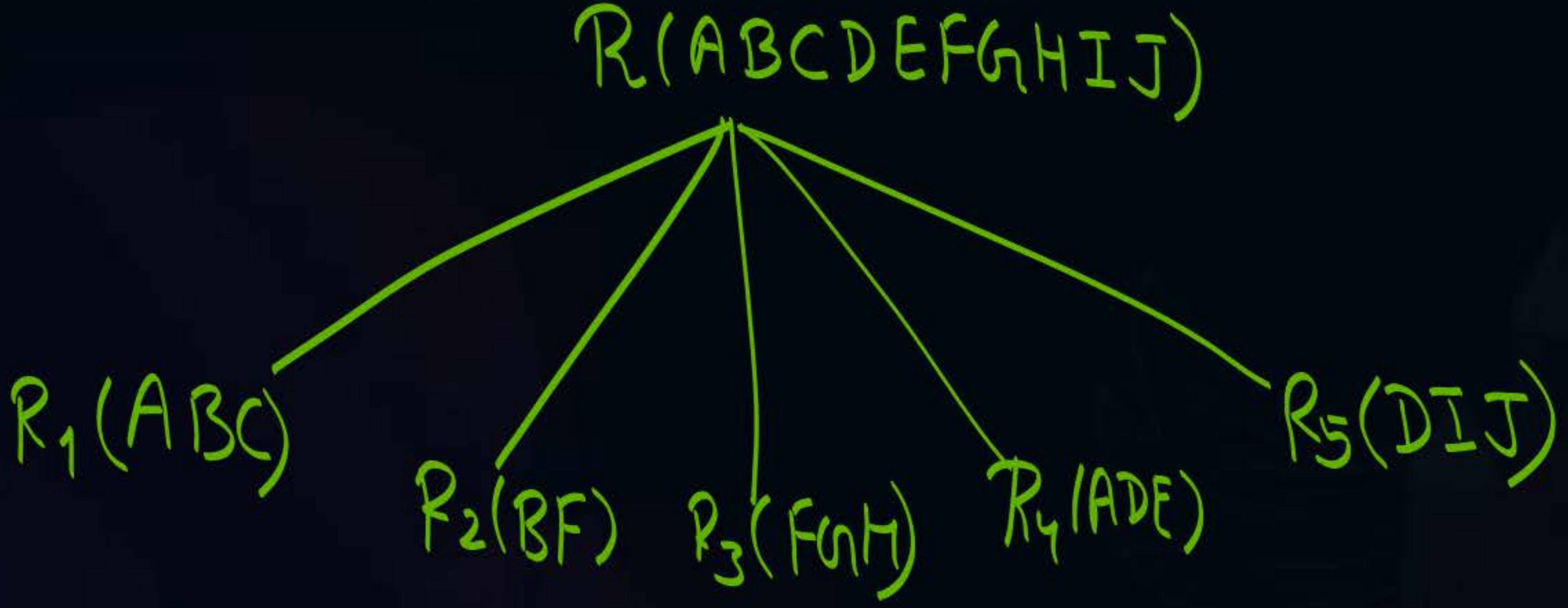
CK : AB

3NF + BCNF + lossless + Dep. preserving

Today's Topic

H.W. ~~#e~~.g. Given R(ABCDEFGHIJ) and F={AB→C, A→DE, B→F, F→GH, D→IJ}

Find the normal form of the relation, and if relation is not already in BCNF then decompose the relation up to BCNF.



H.W.

#e.g. Given R(ABDLPT) and $F=\{B \to PT, T \to L, A \to D\}$

Find the normal form of the relation, and if relation is not already in BCNF then decompose the relation up to BCNF.

#e.g. Given R(ABCDEFGHIJ) and $F=\{AB \rightarrow C, A \rightarrow DE, B \rightarrow F, F \rightarrow GH, D \rightarrow IJ\}$

Find the normal form of the relation, and if relation is not already in BCNF then decompose the relation up to BCNF.

$$F = \left\{ \begin{array}{ll} AB \to C & (BCNF) \\ A \to DE & (1NF) \\ B \to F & (1NF) \\ F \to GH & (2NF) \\ D \to IJ & (2NF) \end{array} \right\}$$

C.K = (AB)

R(ABCDEFGHIJ)

Not in 2NF because of $A \to DE$ & $B \to F$

Let us first decompose w.r.t. $B \to F$

$(BF)^+ = \{BFGH\}$

$R_1(BFGH)$

$$F_1 = \left\{ \begin{array}{l} B \to F\ (BCNF) \\ F \to GH\ (2NF) \end{array} \right\}$$

C.k = B

$R_2(ABCDEIJ)$

lossless

1NF + Lossless + Dep. preserving

$$F_2 = \left\{ \begin{array}{l} AB \to C\ (BCNF) \\ A \to DE\ (1NF) \\ D \to IJ\ (2NF) \end{array} \right\}$$

C.k = (AB)

Decompose w.r.t. $A \to DE$

$(ADE)^+ = \{ADEIJ\}$

$R_3(ADEIJ)$

$$F_3 = \left\{ \begin{array}{l} A \to DE\ (BCNF) \\ D \to IJ\ (2NF) \end{array} \right.$$

C.k = A

$R_4(ABC)$

lossless

$$F_4 = \{AB \to C\ (BCNF)\}$$

C.k = (AB)

2NF + lossless + Dep. preserving

$R_5(FGH)$

$$F_5 = \{F \to GH\}\ (BCNF)$$

Ck = F

$R_6(BF)$

$$F_6 = \{B \to F\}\ (BCNF)$$

C.k = B

$R_7(DIJ)$

$$F_7 = \{D \to IJ\}\ (BCNF)$$

C.k = D

$R_8(ADE)$

$$F_8 = \{A \to DE\}\ (BCNF)$$

C.k = A

3NF + BCNF + lossless join + Dep. preserving

#e.g. Given R(ABDLPT) and F={B→PT, T→L, A→D}

Find the normal form of the relation, and if relation is not already in BCNF then decompose the relation up to BCNF.

$B \longrightarrow PT$ (1NF)

$T \longrightarrow L$ (2NF)

$A \longrightarrow D$ (1NF)

C.K = (AB)

$B \rightarrow PT$
$T \rightarrow L$
$A \rightarrow D$

$R(ABDLPT)$

not in 2NF because of $B \rightarrow PT$ & $A \rightarrow D$

Decompose w.r.t. $B \rightarrow PT$

$(BPT)^+ = \{BPTL\}$

$R_1(BPTL)$

$F_1 = \{ B \rightarrow PT$ (BCNF), $T \rightarrow L$ (2NF) $\}$

C.K = B

$R_2(ABD)$ — lossless

$F_2 = \{ A \rightarrow D$ (1NF) $\}$

C.K = (AB)

1NF + lossless + Dep. preserving

$(TL)^+ = \{T, L\}$

$R_5(TL)$

$F_5 = \{T \rightarrow L\}$ (BCNF)

Ck = T

$R_6(BPT)$ — lossless

$F_6 = \{B \rightarrow PT\}$ (BCNF)

Ck : B

$(AD)^+ = \{AD\}$

$R_3(A, D)$

$F_3 = \{A \rightarrow D\}$ (BCNF)

Ck : A

BCNF

$R_4(AB)$ — lossless

$F_4 = \{\ \}$ ← Empty FD set

C.K = (AB)

No non trivial FD
∴ BCNF

⇒ If there exists a non-trivial FD $X \rightarrow Y$ in which X is not a S.K, then it will cause redundancy in the relation

∵ There is no non-trivial FD in the relⁿ
∴ No redundancy because of FD
Hence Relation is in BCNF

3NF + BCNF + lossless + Dep. preserving

Note :- If there is no non-trivial FD in a relation, then Candidate key of that relation will be formed by Combining all the attributes of that relation, and such relation will always be in BCNF

#e.g. Given R(ABCDE) and F:{A→BC, CD→E, B→D, E→A}

Find the normal form of the relation, and if relation is not already in BCNF then decompose the relation up to BCNF.

$\underset{S.K}{A} \rightarrow BC$ (BCNF)

$\underset{S.K}{CD} \rightarrow E$ (BCNF)

$\underset{P.S.C.K}{B} \rightarrow \underset{P.S.C.K}{D}$ (3NF)

$\underset{S.K}{E} \rightarrow A$ (BCNF)

CK = (A), (E), (CD), (CB)

$A \to BC$
$CD \to E$
$B \to D$
$E \to A$

R(ABCDE) not in BCNF because of $B \to D$

Decompose w.r.t. $B \to D$

$(BD)^+ = \{B, D\}$

lossless

$R_1(BD)$

$F_1 = \{B \to D \text{ (BCNF)}\}$

CK: B

$R_2(ABCE)$

$F_2 = \begin{cases} A \to BCE \text{ (BCNF)} \\ E \to ABC \text{ (BCNF)} \\ BC \to AE \text{ (BCNF)} \end{cases}$

CK: (A), (E), (BC)

BCNF + Lossless Join

⇓

$(CD)^+$ w.r.t $F_1 \cup F_2 = \{C, D\}$

$E \notin (CD)^+$ w.r.t $F_1 \cup F_2$

∴ $CD \to E$ is lost

$R_3(CDE)$

$F_3 = \begin{cases} CD \to E \text{ (BCNF)} \\ E \to CD \text{ (BCNF)} \end{cases}$

Ck: (CD), (E)

We will try to Preserve $CD \to E$ by Creating a new relation Containing attribute C, D & E (if possible)

BCNF + lossless + Dep. preserving

#e.g. Given R(ABCD) and F={AB→CD, D→A }

Find the normal form of the relation, and if relation is not already in BCNF then decompose the relation up to BCNF.

$\underbrace{AB}_{S.K} \longrightarrow CD$ (BCNF)

C.K. = (AB), (DB)

$D \longrightarrow A$ (3NF)

P.S. of One C.K

P.S. of another C.K

$AB \to CD$
$D \to A$ ✓

$R(ABCD)$ is not in BCNF because of $D \to A$

$\therefore$ Decompose w.r.t. $D \to A$

$R_1(AD)$ $R_2(ABC)$
$\bowtie = ?$

$(AD)^+ = \{A, D\}$

lossless

$R_1(AD)$
$F_1 = \{ D \to A \}$ (BCNF)
C.K $= (D)$

$R_2(BCD)$
$F_2 = \{ BD \to C \}$ (BCNF)
S.K
C.K $= (BD)$

BCNF
+
lossless
+
Check w.r.t. $AB \to CD$

$(AB)^+$ w.r.t. $F_1 \cup F_2 = \{A, B\}$

$C, D \notin (AB)^+$ w.r.t. $F_1 \cup F_2$

$\therefore AB \to CD$ is lost

Q: Can we create a new relation $R_3(ABCD)$ to preserve $AB \to CD$

Ans: NO, If we create a sub-relation $R_3(ABCD)$ then $D \to A$ will also be present in its FD set and "$D \to A$" will be in 3NF.

i.e. Decomposition will not be in BCNF, as it remains in 3NF

Note:-

1. Upto 3NF we can always ensure lossless join decomposition as well as dependency Preserving decomposition

2. While decomposing a relation into BCNF some times (Not always) it may not be possible to preserve some of the functional dependencies of the original relation, but we can always ensure lossless join decomposition.

3. Most adequate normal form of the database is 3NF, because we can always ensure lossless join decomposition as well as dep. preserving decomposition {i.e, No loss of information}

(4) In a relation if all attributes are prime attributes, then the relation is at least in 3NF.

(5) If all candidate keys of the relation are simple candidate keys, then partial dependency can not exist in the relation, therefore relation will be at least in 2NF.

(6) In a relation if all attributes are prime attributes, and all candidate keys of the relation are simple candidate keys, then relation is always in BCNF

(7) A binary relation {i.e., a relation with exactly two attributes} is always in BCNF.

e.g. Let R(AB) is a relation then different types of FD sets possible w.r.t. relation R are

$F_1 = \{\underset{SK}{A} \rightarrow B\}$ BCNF

CK = A

$F_2 = \{\underset{SK}{B} \rightarrow A\}$ BCNF

CK = B

$F_3 = \{\underset{S.K}{A} \rightarrow B, \ \underset{S.K}{B} \rightarrow A\}$ BCNF BCNF

CK = (A), (B)

$F_4 = \{\ \}$ Empty

CK = (AB)

BCNF

(8) If a relation is in BCNF, then there will be no redundancy in that relation because of functional dependencies,

but redundancy may still be present in the relation because of multi-valued dependencies.

Multi-valued dependency

eg:

Sid	Cid	Mob_NO
S_1	C_1	M_1
S_1	C_1	M_2
S_1	C_2	M_1
S_1	C_2	M_2
S_2	C_2	M_2

Non-trivial FDs that can be defined w.r.t. three attributes

$Sid \not\to Cid$

$Sid \not\to Mob\_NO$

$Cid \not\to Sid$

$Cid \not\to Mob\_NO$

$Mob\_NO \not\to Sid$

$Mob\_NO \not\to Cid$

$Sid, Cid \not\to Mob\_NO$

$Sid, Mob\_NO \not\to Cid$

$Cid, Mob\_NO \not\to Sid$

None of this non-trivial FDs Exist in the relation

$\downarrow$

$\therefore$ Relation is in BCNF

$\downarrow$

But redundancy is still present in the relation

Topic : Multivalued dependency

"X multi valued determines Y" is denoted by $X \rightarrow\rightarrow Y$

- If there exist two or more independent attributes which are dependent on some other set of attributes then multi-valued dependency will (may) exist in the relation

★ Formal definition of MVD :

Let R is a relation, and X and Y are two sets of attributes from relation R { let us define Z = $\underbrace{\text{Attributes of } R - \text{Attributes in } `X \cup Y'}$

i.e., Z is the set of remaining attributes

If there exist '4' tuples $t_1, t_2, t_3, t_4 \in R$ s.t.,

$$t_1.X = t_2.X = t_3.X = t_4.X$$

and $t_1.Y = t_2.Y$ and $t_3.Y = t_4.Y$

and $t_1.Z = t_3.Z$ and $t_2.Z = t_4.Z$

then Multi-valued dependency $X \rightarrow\rightarrow Y$ exist in R

"if" cond is true then "then" condition is definitely true.

But if 'if' condn is false, then also "then" condn may be true

X Z Y

X Y Z

		Sid	Cid	Mob_No
t_1	t_1	S_1	C_1	M_1
t_3	t_2	S_1	C_1	M_2
t_2	t_3	S_1	C_2	M_1
t_4	t_4	S_1	C_2	M_2
		S_2	C_2	M_2

w.r.t this numbering of tuples
Sid →→ Mob_no. will also
exist in relation R.

w.r.t this numbering of tuples
Sid →→ Cid exist in the relation

* Another definition w.r.t. MVD :-

Whenever we swap the values of attribute set Y in two tuples {let t_1 & t_2} which agree on the value of attribute set X {i.e. $t_1 \cdot X = t_2 \cdot X$} and if the resulting tuple was already a member of the relation, then $X \rightarrow\rightarrow Y$ exists in the relation.

Sid	Cid	Mob_No
S_1	C_1	M_1
S_1	C_1	M_2
S_1	C_2	M_1
S_1	C_2	M_2
S_2	C_2	M_2

same Cid

∴ swap Mob_No

Q: Check whether Cid $\rightarrow\rightarrow$ Mob_No exist in the relation or not

$\Rightarrow$ S_1 C_2 M_2

$\Rightarrow$ S_2 C_2 M_1 → it was not present in original relation

$\Downarrow$

Hence, Cid $\rightarrow\rightarrow$ Mob_no does not exist in the relation

2 mins Summary

Topic — Decomposition of relation up to BCNF

Topic — Multi-valued dependency and 4NF

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THANK - YOU

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