



### **EXPERIMENT - 4**

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**Question 1: Consider a relation R having attributes as R(ABCD), functional dependencies are given below:  $AB \rightarrow C$ ,  $C \rightarrow D$ ,  $D \rightarrow A$**

**Identify the set of candidate keys possible in relation R. List all the set of prime and non-prime attributes and find highest normal form.**

**Solution:** Candidate Key Derivation:

- Compute closures to find minimal keys:  $(AB)^+ = \{A, B, C, D\}$   
 $(BC)^+ = \{B, C, D, A\}$   
 $(BD)^+ = \{B, D, A, C\}$   
 $(A)^+ = \{A\} \rightarrow A$  does not give B or C directly.  
 $(C)^+ = \{C, D, A\}$  ( $C \rightarrow D$ ,  $D \rightarrow A$ ) — missing B.  
 $(D)^+ = \{D, A, C\}$  ( $D \rightarrow A$ , A no new C except via AB) — missing B.
- Minimal sets whose closure is all attributes are AB, BC, BD.

**Keys:**

Candidate Keys =  $\{AB, BC, BD\}$

**Attributes:**

Prime Attributes =  $\{A, B, C, D\}$

Non-Prime Attributes =  $\{\}$  (none)

**Normalization:**

**BCNF**

- $AB \rightarrow C$ : AB is a candidate key  $\rightarrow$  OK.
- $C \rightarrow D$ : C is not a superkey  $\rightarrow$  violation.
- $D \rightarrow A$ : D is not a superkey  $\rightarrow$  violation.

$\Rightarrow$  Not in BCNF.

## 3NF

- $AB \rightarrow C$ : LHS is key  $\rightarrow$  OK.
- $C \rightarrow D$ : D is prime (every attribute is prime)  $\rightarrow$  OK.
- $D \rightarrow A$ : A is prime  $\rightarrow$  OK.

$\Rightarrow$  All FDs satisfy 3NF conditions.

Relation is in 3NF.

**Highest Normal Form = 3NF**

Question 2 : Relation R(ABCDE) having functional dependencies as:

$A \rightarrow D$ ,

$B \rightarrow A$ ,

$BC \rightarrow D$ ,

$AC \rightarrow BE$

Identify the set of candidate keys possible in relation R. List all the set of prime and non prime attributes and find highest normal form.

**Solution:** Candidate Key Derivation:

- Compute closures to find minimal keys:
  - $(A)^+ = \{A, D\}$  (from  $A \rightarrow D$ ) — missing B, C, E.
  - $(B)^+ = \{B, A, D\}$  ( $B \rightarrow A$ ,  $A \rightarrow D$ ) — missing C, E.
  - $(C)^+ = \{C\}$  — gives nothing else alone.
  - $(AC)^+ = \{A, C, B, E, D\}$  ( $AC \rightarrow BE$  gives B, E;  $B \rightarrow A$  already;  $A \rightarrow D$ ) = ABCDE.
  - $(BC)^+ = \{B, C, A, D, E\}$  ( $B \rightarrow A$ ,  $AC \rightarrow BE$  or  $BC \rightarrow D$  then  $AC \rightarrow BE$ ) = ABCDE.
  - $(AB)^+ = \{A, B, D\}$  (from  $B \rightarrow A$ ,  $A \rightarrow D$ ) — missing C, E.
- Minimal sets whose closure is all attributes are AC and BC.

**Keys:**

Candidate Keys =  $\{AC, BC\}$

**Attributes:**

Prime Attributes =  $\{A, B, C\}$

Non Prime Attributes =  $\{D, E\}$

**Normalization:**

BCNF:

- $A \rightarrow D$ : A is not a key  $\rightarrow$  violation.
- $B \rightarrow A$ : B is not a key  $\rightarrow$  violation.
- $BC \rightarrow D$ : BC is a candidate key  $\rightarrow$  OK.

- $AC \rightarrow BE$ : AC is a candidate key  $\rightarrow$  OK.  
 $\Rightarrow$  Not in BCNF.

3NF: For each FD, check LHS is key or RHS attributes are prime:

- $A \rightarrow D$ : A not a key and D is non-prime  $\rightarrow$  violation.
- $B \rightarrow A$ : B not a key but A is prime  $\rightarrow$  OK.  $BC \rightarrow D$ : LHS is key  $\rightarrow$  OK.
- $AC \rightarrow BE$ : LHS is key  $\rightarrow$  OK.  
 $\Rightarrow$  Not in 3NF (because of  $A \rightarrow D$ ).

2NF: Check partial dependencies on part of any candidate key (non-prime depending on part of a key):

Candidate keys: AC and BC. Non-prime attributes are {D, E}.

$A \rightarrow D$ : A is a proper subset of the key AC and determines non-prime D  $\rightarrow$  partial dependency  $\rightarrow$  violation.  $\Rightarrow$  Not in 2NF.

1NF: Attributes are atomic  $\rightarrow$  satisfies 1NF.

**Highest Normal Form = 1NF**

**Question 3. Consider a relation R having attributes as R(ABCDE), functional dependencies are given below:**

**$B \rightarrow A, A \rightarrow C, BC \rightarrow D, AC \rightarrow BE$**

**Identify the set of candidate keys possible in relation R. List all the set of prime and nonprime attributes and find highest normal form.**

**Solution:** Candidate Key Derivation:

$(A)^+ = \{A, C\}$  (from  $A \rightarrow C$ ); from  $AC \rightarrow BE$  get B,E; with B and C,  $BC \rightarrow D$  gives D  $\rightarrow$  so  $(A)^+ = \{A, B, C, D, E\}$ .

$(B)^+ = \{B, A\}$  (from  $B \rightarrow A$ ); then  $A \rightarrow C$  gives C;  $AC \rightarrow BE$  gives E;  $BC \rightarrow D$  gives D  $\rightarrow$  so  $(B)^+ = \{A, B, C, D, E\}$ .

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

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

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

**Keys:**

Candidate Keys = {A, B}

## Attributes:

Prime Attributes = {A, B}

Non-Prime Attributes = {C, D, E}

## Normalization:

### BCNF

- $B \rightarrow A$  : B is a candidate key  $\rightarrow$  OK.
  - $A \rightarrow C$  : A is a candidate key  $\rightarrow$  OK.
  - $BC \rightarrow D$  : BC contains B (a key), so BC is a superkey  $\rightarrow$  OK.
  - $AC \rightarrow E$  : AC contains A (a key), so AC is a superkey  $\rightarrow$  OK.
- $\Rightarrow$  All FDs have superkey LHS  $\rightarrow$  Relation is in BCNF.

### 3NF

Since BCNF holds, 3NF is also satisfied.

### 2NF

Candidate keys are single attributes, so there are no partial dependencies on a part of a composite key  $\rightarrow$  satisfies 2NF.

### 1NF

Attributes are atomic  $\rightarrow$  satisfies 1NF.

## Highest Normal Form = BCNF

**Question 4. Consider a relation R having attributes as R(ABCDEF), functional dependencies are given below:**

**$A \rightarrow BCD$ ,  $BC \rightarrow DE$ ,  $B \rightarrow D$ ,  $D \rightarrow A$**

**Identify the set of candidate keys possible in relation R. List all the set of prime and nonprime attributes and find highest normal form.**

**Solution:** Candidate Key Derivation:

- Attribute F never appears on the RHS of any dependency, so it must be included in every candidate key.
- Compute closures (with F included):
- $(AF)^+$ :  $A \rightarrow BCD$  gives {A, B, C, D}; with  $BC \rightarrow DE$  we add E  $\rightarrow$  {A, B, C, D, E}; including F  $\rightarrow (AF)^+ = \{A, B, C, D, E, F\}$ .
- $(BF)^+$ :  $B \rightarrow D$ ,  $D \rightarrow A$ , then  $A \rightarrow BCD$  gives {A, B, C, D}; with  $BC \rightarrow DE$  we get E  $\rightarrow$  {A, B, C, D, E}; including F  $\rightarrow (BF)^+ = \{A, B, C, D, E, F\}$ .
- $(DF)^+$ :  $D \rightarrow A$ , then  $A \rightarrow BCD$  gives {A, B, C, D}; with  $BC \rightarrow DE$  we get E  $\rightarrow$  {A, B, C, D, E}; including F  $\rightarrow (DF)^+ = \{A, B, C, D, E, F\}$ .
- $(CF)^+ = \{C, F\}$  (C alone doesn't generate others) — not a key.

- $(EF)^+ = \{E, F\}$  — not a key.
- Minimal keys are  $\{AF\}$ ,  $\{BF\}$ ,  $\{DF\}$ .

## Keys:

Candidate Keys =  $\{AF, BF, DF\}$

## Attributes:

Prime Attributes =  $\{A, B,$

$D, F\}$  Non-Prime

Attributes =  $\{C, E\}$

## Normalization:

### BCNF

- $A \rightarrow BCD$ : A is not a superkey  $\rightarrow$  violation.
- $BC \rightarrow DE$ : BC is not a superkey  $\rightarrow$  violation.
- $B \rightarrow D$ : B is not a superkey  $\rightarrow$  violation.
- $D \rightarrow A$ : D is not a superkey  $\rightarrow$  violation.

$\Rightarrow$  Not in BCNF.

### 3NF

For each FD, either LHS is a key or RHS is prime:

- $A \rightarrow BCD$ : A not a key, RHS contains non-prime C, E  $\rightarrow$  violation.
- $BC \rightarrow DE$ : BC not a key, RHS contains non-prime E  $\rightarrow$  violation.
- $B \rightarrow D$ : D is prime  $\rightarrow$  OK. •  $D \rightarrow A$ : A is prime  $\rightarrow$  OK.

$\Rightarrow$  Not in 3NF.

### 2NF

Candidate keys are  $\{AF, BF, DF\}$ . Non-prime attributes =  $\{C, E\}$ .

- $A \rightarrow C$ : A is part of key AF and determines non-prime C  $\rightarrow$  partial dependency  $\rightarrow$  violation.

$\Rightarrow$  Not in 2NF.

- **1NF**: Attributes are atomic  $\rightarrow$  satisfied.

**Highest Normal Form = 1NF**

**Question 5. Designing a student database involves certain dependencies which are listed below:**

- $X \rightarrow Y$
- $WZ \rightarrow X$
- $WZ \rightarrow Y$
- $Y \rightarrow W$
- $Y \rightarrow X$
- $Y \rightarrow Z$

**The task here is to remove all the redundant FDs for efficient working of the student database management system.**

**Solution:** We are given the relation  $R(W, X, Y, Z)$  with functional dependencies. Our aim is to find and remove the redundant dependencies

Write the FDs again -

1.  $X \rightarrow Y$
2.  $WZ \rightarrow X$
3.  $WZ \rightarrow Y$
4.  $Y \rightarrow W$
5.  $Y \rightarrow X$
6.  $Y \rightarrow Z$

Check redundancy one by one -

- Check FD (3):  $WZ \rightarrow Y$   
From (2)  $WZ \rightarrow X$  and (1)  $X \rightarrow Y$ , we can derive  $WZ \rightarrow Y$ . So, FD (3) is redundant.
- Check FD (5):  $Y \rightarrow X$   
From (6)  $Y \rightarrow Z$  and (4)  $Y \rightarrow W$ , we already have  $(W, Z)$ .  
Now,  $(W, Z) \rightarrow X$  (from FD 2).  
Hence, from  $Y$  we can derive  $W$  and  $Z$ , then  $(WZ \rightarrow X)$ , so  $Y \rightarrow X$  is also redundant.

Final minimal cover

The essential dependencies are:

1.  $X \rightarrow Y$
2.  $WZ \rightarrow X$
3.  $Y \rightarrow W$
4.  $Y \rightarrow Z$

After removing redundant dependencies, the minimal set of functional dependencies is:

- $X \rightarrow Y$
- $WZ \rightarrow X$
- $Y \rightarrow W$
- $Y \rightarrow Z$

This is the minimal cover of the given FDs, and hence these will be used for efficient working of the student database management system.

**Question 6.** Debix Pvt Ltd needs to maintain database having dependent attributes ABCDEF. These attributes are functionally dependent on each other for which functionally dependency set F given as:

**{A → BC, D → E, BC → D, A → D}** Consider a universal relation R1(A, B, C, D, E, F) with functional dependency set F, also all attributes are simple and take atomic values only. Find the highest normal form along with the candidate keys with prime and non- prime attribute.

**Solution:** Candidate Key Derivation:

- Attribute F never appears on the RHS of any dependency, so it must be included in every candidate key.  
Compute closures (with F included):
- (AF)<sup>+</sup> :  
 $A \rightarrow BC \rightarrow \{A, B, C\}$   
 $BC \rightarrow D \rightarrow \{A, B, C, D\}$   
 $D \rightarrow E \rightarrow \{A, B, C, D, E\}$   
Add F → (AF)<sup>+</sup> = {A, B, C, D, E, F}
- (BF)<sup>+</sup> :  
Start with {B, F}. No FD gives A. Missing A → can't reach all attributes.  
⇒ Not a key.
- (CF)<sup>+</sup> :  
Start with {C, F}. No FD gives A. Missing A → not a key.
- (DF)<sup>+</sup> :  
 $D \rightarrow E \rightarrow \{D, E, F\}$ . Still missing A, B, C → not a key.
- (EF)<sup>+</sup> :  
Start with {E, F}. No FD gives A. Missing A, B, C, D → not a key. Thus the only minimal key = {AF}.

**Keys:**

Candidate Keys = {AF}

**Attributes:**

- Prime Attributes = {A, F}
- Non-Prime Attributes = {B, C, D, E}

**Normalization:**

**BCNF**



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$A \rightarrow BC$  : A not a superkey  $\rightarrow$  violation.  $A \rightarrow D$  : A not a superkey  $\rightarrow$  violation.  $BC \rightarrow D$  : BC not a superkey  $\rightarrow$  violation.  $D \rightarrow E$  : D

not a superkey  $\rightarrow$  violation.

$\Rightarrow$  Not in BCNF

3NF

$A \rightarrow BC$  : A not a key, RHS has non-prime (B,C)  $\rightarrow$  violation.  $A \rightarrow D$  : A not a key, D non-prime  $\rightarrow$  violation.

$BC \rightarrow D$  : BC not a key, D non-prime  $\rightarrow$  violation.  $D \rightarrow E$  : D not a key, E non-prime  $\rightarrow$  violation.

$\Rightarrow$  Not in 3NF

2NF

Candidate key = {AF}.

$A \rightarrow BC$  : A is part of candidate key and determines non-prime attributes  $\rightarrow$  partial dependency  $\rightarrow$  violation.

$A \rightarrow D$  : Same partial dependency  $\rightarrow$  violation.

$\Rightarrow$  Not in 2NF

1NF

All attributes are atomic  $\rightarrow$  satisfied.

**Highest Normal Form = 1NF**