

## 0.6 Functional Dependency Replacement

you-said

Replace all functional dependencies of type  $\rightarrow 1$  and  $\rightarrow 2$  by  $\rightarrow 1 \cup 2$  in  $F = \{\{A, B, C\} \rightarrow \{D\}, \{A, B, C\} \rightarrow \{D, E\}, \{D\} \rightarrow \{A, B\}, \{E\} \rightarrow \{A, C\}\}$ .

ChatGPT said:

To replace the functional dependencies of the form  $\alpha \rightarrow \beta_1 \rightarrow 1$  and  $\alpha \rightarrow \beta_2 \rightarrow 2$  with  $\alpha \rightarrow \beta_1 \cup \beta_2 \rightarrow 12$ , we combine the right-hand sides of dependencies that have the same left-hand side.

Given the set of functional dependencies:

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

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

step-1-identify-dependencies-with-the-same-left-hand-side

### Step 1: Identify dependencies with the same left-hand side

- $\{A, B, C\} \rightarrow \{D\}$  and  $\{A, B, C\} \rightarrow \{D, E\}$  share the same left-hand side.

step-2-union-the-right-hand-sides

### Step 2: Union the right-hand sides

- Combine the right-hand sides:  $\{D\} \cup \{D, E\} = \{D, E\}$
- So, we replace these two dependencies with  $\{A, B, C\} \rightarrow \{D, E\}$ .

step-3-final-set-of-functional-dependencies

### Step 3: Final Set of Functional Dependencies

The final set after the replacement is:

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

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

This is the updated set of functional dependencies.

you-said-1

This is the algorithm to find extraneous attributes in a set of functional dependencies  
 F: Given  $\rightarrow : \bullet$  a is extraneous if  $(- a) +$  under F  $\bullet$  a is extraneous if  $a +$  under  $F' = (F - \{ \rightarrow \}) \cup \{ \rightarrow (- a) \}$  The algorithm of Closure of under F (+) is: result := Do result\_previous = result For each  $\rightarrow$  in F: If ( result): result := result Union While (result\_previous  $\neq$  result) Return result Show if A is an extraneous attribute in  $\{A, B, C\} \rightarrow \{D, E\}$  in F'

ChatGPT said:

To determine whether AA is an extraneous attribute in the functional dependency  $\{A, B, C\} \rightarrow \{D, E\}$  within the set  $F' = \{\{A, B, C\} \rightarrow \{D, E\}, \{D\} \rightarrow \{A, B\}, \{E\} \rightarrow \{A, C\}\}$  we follow the algorithm steps for checking if an attribute is extraneous.

step-1-check-if-aa-is-extraneous-in-left.-abcrightharrow-de-right.abcede

**Step 1: Check if AA is extraneous in  $\{A, B, C\} \rightarrow \{D, E\}$**   
**Check if AA is extraneous in  $\{A, B, C\} \rightarrow \{D, E\}$**

To check if AA is extraneous in the left-hand side  $\{A, B, C\} \rightarrow \{D, E\}$ , we need to compute the closure of  $\{B, C\}$  (which is  $\{A, B, C\} - A$ ) under the set of functional dependencies F'.

step-2-compute-bcbc-under-fprimef

Use the closure algorithm to find  $\{B, C\}^+ \{B, C\}^+.$

• **Initialization:**  $result = \{B, C\}$

• **First Iteration:**

- Check  $\{A, B, C\} \rightarrow \{D, E\}$ : This doesn't apply since  $\{A, B, C\}$  is not a subset of  $\{B, C\}$ .
- Check  $\{D\} \rightarrow \{A, B\}$ : This doesn't apply because  $D \notin \{B, C\}$ .
- Check  $\{E\} \rightarrow \{A, C\}$ : This doesn't apply because  $E \notin \{B, C\}$ .

After the first iteration,  $result = \{B, C\}$ .

• **Second Iteration:** No changes, so the closure stabilizes at  $\{B, C\}$ .

Thus,  $\{B, C\}^+ = \{B, C\}$ .

step-3-compare-closure-result-with-dede

**Step 3: Compare Closure Result with  $\{D, E\}$**

Since  $\{B, C\}^+ = \{B, C\} \cup \{B, C\}^+ = \{B, C\}$  does not contain  $\{D, E\}$ ,  $AA$  is **not extraneous** in the left-hand side  $\{A, B, C\} \rightarrow \{D, E\}$ .

you-said-2

Show if  $B$  is an extraneous attribute in  $\{A, B, C\} \rightarrow \{D, E\}$  in  $F'$

ChatGPT said:

To determine if  $B$  is an extraneous attribute in  $\{A, B, C\} \rightarrow \{D, E\}$  under the set  $F' = \{\{A, B, C\} \rightarrow \{D, E\}, \{D\} \rightarrow \{A, B\}, \{E\} \rightarrow \{A, C\}\}$

we follow the algorithm to check if  $B$  is extraneous in the left-hand side.

step-1-check-if-bb-is-extraneous-in-left.-abcrightarrow-de-right.abcd

**Step 1: Check if  $B$  is extraneous in  $\{A, B, C\} \rightarrow \{D, E\}$**

**Check if  $B$  is extraneous in  $\{A, B, C\} \rightarrow \{D, E\}$**

To check if  $B$  is extraneous in  $\{A, B, C\} \rightarrow \{D, E\}$ , we compute the closure of  $\{A, C\}$  (i.e.,  $\{A, B, C\} - B$ ) under the set of functional dependencies  $F'$ .

step-2-compute-acac-under-fprimef

**Step 2: Compute  $\{A, C\}^+$  under  $F'$**

Use the closure algorithm to find  $\{A, C\}^+$ .

• **Initialization:**  $result = \{A, C\}$

• **First Iteration:**

- Check  $\{A, B, C\} \rightarrow \{D, E\}$ : This doesn't apply because  $\{A, B, C\}$  is not a subset of  $\{A, C\}$ .
- Check  $\{D\} \rightarrow \{A, B\}$ : This doesn't apply because  $D \notin \{A, C\}$ .
- Check  $\{E\} \rightarrow \{A, C\}$ : This doesn't apply because  $E \notin \{A, C\}$ .

After the first iteration,  $result = \{A, C\}$ .

• **Second Iteration:** No new changes, so the closure stabilizes at  $\{A, C\}$ .

Thus,  $\{A, C\}^+ = \{A, C\}$ .

step-3-compare-closure-result-with-dede-1

### Step 3: Compare Closure Result with $\{D, E\}$ Step 3: Compare Closure Result with $\{D, E\}$

Since  $\{A, C\}^+ = \{A, C\} \cup \{A, C\}^+ = \{A, C\}$  does not contain  $\{D, E\}$ ,  $B$  is **not extraneous** in the left-hand side  $\{A, B, C\} \rightarrow \{D, E\}$ .

you-said-3

Show if  $C$  is an extraneous attribute in  $\{A, B, C\} \rightarrow \{D, E\}$  in  $F'$

ChatGPT said:

To determine if  $C$  is an extraneous attribute in the functional dependency  $\{A, B, C\} \rightarrow \{D, E\}$  under the set  $F' = \{\{A, B, C\} \rightarrow \{D, E\}, \{D\} \rightarrow \{A, B\}, \{E\} \rightarrow \{A, C\}\}$ , we follow the procedure to check if  $C$  is extraneous in the left-hand side.

step-1-check-if-cc-is-extraneous-in-left.-abcrightrightarrow-de-right.abcd

### Step 1: Check if $C$ is extraneous in $\{A, B, C\} \rightarrow \{D, E\}$ Step 1: Check if $C$ is extraneous in $\{A, B, C\} \rightarrow \{D, E\}$

To check if  $C$  is extraneous in the left-hand side, we compute the closure of  $\{A, B\}$  (i.e.,  $\{A, B, C\} - C$ ) under the set of functional dependencies  $F'$ .

step-2-compute-abab-under-fprimef

### Step 2: Compute $\{A, B\}^+$ under $F'$ Step 2: Compute $\{A, B\}^+$ under $F'$

Use the closure algorithm to find  $\{A, B\}^+$ .

- **Initialization:**  $result = \{A, B\}$
- **First Iteration:**

- Check  $\{A, B, C\} \rightarrow \{D, E\}$ : This doesn't apply because  $\{A, B, C\}$  is not a subset of  $\{A, B\}$ .
- Check  $\{D\} \rightarrow \{A, B\}$ : This doesn't apply because  $D \notin \{A, B\}$ .
- Check  $\{E\} \rightarrow \{A, C\}$ : This doesn't apply because  $E \notin \{A, B\}$ .

After the first iteration,  $result = \{A, B\}$ .

- **Second Iteration:** No changes, so the closure stabilizes at  $\{A, B\}$ .

Thus,  $\{A, B\}^+ = \{A, B\}$ .

step-3-compare-closure-result-with-dede-2

### Step 3: Compare Closure Result with $\{D, E\}$ Step 3: Compare Closure Result with $\{D, E\}$

Since  $\{A, B\}^+ = \{A, B\}\{A, B\}^+ = \{A, B\}$  does not contain  $\{D, E\}$ ,  $CC$  is **not extraneous** in the left-hand side  $\{A, B, C\} \rightarrow \{D, E\}$ .

you-said-4

Show if  $D$  is an extraneous attribute in  $\{A, B, C\} \rightarrow \{D, E\}$  in  $F'$

ChatGPT said:

To determine if  $DD$  is an extraneous attribute in the functional dependency  $\{A, B, C\} \rightarrow \{D, E\}$  under the set  $F' = \{\{A, B, C\} \rightarrow \{D, E\}, \{D\} \rightarrow \{A, B\}, \{E\} \rightarrow \{A, C\}\}$ , we follow the procedure for checking if  $DD$  is extraneous in the right-hand side.

step-1-check-if-dd-is-extraneous-in-left.- $\{A, B, C\} \rightarrow \{D, E\}$

### Step 1: Check if $DD$ is extraneous in $\{A, B, C\} \rightarrow \{D, E\}$ Step 1: Check if $DD$ is extraneous in $\{A, B, C\} \rightarrow \{D, E\}$

To check if  $DD$  is extraneous in the right-hand side, we need to compute the closure of  $\{A, B, C\}$  under the set of functional dependencies  $F''$ , which is:

$$F'' = F' - \{\{A, B, C\} \rightarrow \{D, E\}\} \cup \{\{A, B, C\} \rightarrow \{E\}\}$$

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

So, the new set  $F''$  becomes:

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

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

step-2-compute- $\{A, B, C\}^+$  under  $F''$

### Step 2: Compute $\{A, B, C\}^+$ under $F''$ Step 2: Compute $\{A, B, C\}^+$ under $F''$

We now compute the closure of  $\{A, B, C\}$  under  $F''$ :

- **Initialization:**  $result = \{A, B, C\}$

- **First Iteration:**

- Check  $\{A, B, C\} \rightarrow \{E\}$ : Since  $\{A, B, C\} \subseteq \{A, B, C, E\}$ , we add  $EE$  to the result. Now  $result = \{A, B, C, E\}$ .
- Check  $\{D\} \rightarrow \{A, B\}$ : This doesn't apply because  $D \notin \{A, B, C, E\}$ .
- Check  $\{E\} \rightarrow \{A, C\}$ : Since  $E \subseteq \{A, B, C, E\}$ , we add  $AA$  and  $CC$  to the result, but they are already in the set.

After the first iteration,  $result = \{A, B, C, E\}$  result={A,B,C,E}.

- **Second Iteration:** No further changes, so the closure stabilizes at  $\{A, B, C, E\}$  {A,B,C,E}.

Thus,  $\{A, B, C\}^+ = \{A, B, C, E\}$  {A,B,C}+= {A,B,C,E}.

step-3-compare-closure-result-with-dd

### Step 3: Compare Closure Result with DD

Since  $\{A, B, C\}^+ = \{A, B, C, E\}$  {A,B,C}+= {A,B,C,E} does **not** contain  $DD$ , it means that  $DD$  is **extraneous** in the right-hand side  $\{A, B, C\} \rightarrow \{D, E\}$  {A,B,C}→{D,E}.

conclusion

### Conclusion:

$DD$  is an **extraneous** attribute in the functional dependency  $\{A, B, C\} \rightarrow \{D, E\}$  {A,B,C}→{D,E}.

you-said-5

This is the definition of extraneous attributes: Given  $\rightarrow$  : •  $a$  is extraneous if ( - a)+ under  $F$  •  $a$  is extraneous if  $a$  + under  $F' = (F - \{ \rightarrow \}) \cup \{ \rightarrow (- a) \}$

ChatGPT said:

Let's use the definition you've provided to determine whether  $DD$  is an extraneous attribute in the right-hand side of the functional dependency  $\{A, B, C\} \rightarrow \{D, E\}$  {A,B,C}→{D,E}

under the set  $F' = \{ \{A, B, C\} \rightarrow \{D, E\}, \{D\} \rightarrow \{A, B\}, \{E\} \rightarrow \{A, C\} \}$  F={ {A,B,C}→{D,E}, {D}→{A,B}, {E}→{A,C} }

step-1-check-if-dd-is-extraneous-in-left.-abcrightarrow-de-right.abcde-1

### Step 1: Check if $DD$ is extraneous in $\{A, B, C\} \rightarrow \{D, E\}$ {A,B,C}→{D,E}

### Check if $DD$ is extraneous in $\{A, B, C\} \rightarrow \{D, E\}$ {A,B,C}→{D,E}

Using the rule from the definition:

- $a \in \beta a$  (in this case,  $a = D$  a=D) is extraneous if  $D \in \alpha^+ D$  (i.e.,  $D \in \{A, B, C\}^+ D$  {A,B,C}+) under  $F'' = (F' - \{ \{A, B, C\} \rightarrow \{D, E\} \}) \cup \{ \{A, B, C\} \rightarrow \{E\} \}$  F=(F-{ {A,B,C}→{D,E} }) { {A,B,C}→{E} }

We will now compute  $\{A, B, C\}^+ \{A, B, C\}$  + under the modified set  $F''$  F.

step-2-compute-abcabc-under-fprimeprimef-1

### Step 2: Compute $\{A, B, C\}^+ \{A, B, C\}$ + under $F''$ F

### under $F''$ F

The modified set  $F''$  F becomes:

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

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

Now, let's compute the closure of  $\{A, B, C\}$  under  $F''$ :

- **Initialization:**  $result = \{A, B, C\}$

- **First Iteration:**

- Check  $\{A, B, C\} \rightarrow \{E\}$ : Since  $\{A, B, C\} \subseteq result$ , we add  $EE$  to  $result$ . Now,  $result = \{A, B, C, E\}$ .
- Check  $\{D\} \rightarrow \{A, B\}$ : This doesn't apply because  $D \notin result$ .
- Check  $\{E\} \rightarrow \{A, C\}$ : Since  $E \in result$ , we add  $AA$  and  $CC$  to the result, but they are already in  $result$ .

After the first iteration,  $result = \{A, B, C, E\}$ .

- **Second Iteration:** No further changes, so the closure stabilizes at  $\{A, B, C, E\}$ .

Thus,  $\{A, B, C\}^+ = \{A, B, C, E\}$ .

step-3-compare-closure-result-with-dd-1

### Step 3: Compare Closure Result with DD

Since  $\{A, B, C\}^+ = \{A, B, C, E\}$  does **not** contain  $DD$ , it means that  $DD$  is **not** in  $\{A, B, C\}^+$ .

conclusion-1

### Conclusion:

According to the definition,  $DD$  is **not extraneous** in the right-hand side  $\{A, B, C\} \rightarrow \{D, E\}$ .

Show if  $E$  is an extraneous attribute in  $\{A, B, C\} \rightarrow \{D, E\}$  in  $F'$ . This is the definition of extraneous attributes: Given  $\rightarrow$ : •  $a$  is extraneous if  $(\rightarrow - a)^+$  under  $F$  •  $a$  is extraneous if  $a \rightarrow$  under  $F' = (F - \{\rightarrow\}) \cup \{a \rightarrow\}$

ChatGPT said:

Let's determine whether  $EE$  is an extraneous attribute in the functional dependency  $\{A, B, C\} \rightarrow \{D, E\}$  under the set  $F' = \{\{A, B, C\} \rightarrow \{D, E\}, \{D\} \rightarrow \{A, B\}, \{E\} \rightarrow \{A, C\}\}$ .

step-1-use-the-definition-of-extraneous-attributes

### Step 1: Use the Definition of Extraneous Attributes

According to the definition:

- $a \in \beta a$  (in this case,  $a = E$ ) is extraneous if  $E \in \alpha^+ E$  (i.e.,  $E \in \{A, B, C\}^+ E$ ) under  $F'' = (F' - \{\{A, B, C\} \rightarrow \{D, E\}\}) \cup \{\{A, B, C\} \rightarrow \{D\}\}$

We now modify the set of functional dependencies  $F'$  to  $F''$  by removing  $\{A, B, C\} \rightarrow \{D, E\}$  and adding  $\{A, B, C\} \rightarrow \{D\}$ . So,  $F''$  becomes:

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

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

step-2-compute-abcabc-under-fprimeprimef-2

**Step 2: Compute  $\{A, B, C\}^+ \{A, B, C\}^+$  under  $F''$**

Let's compute the closure of  $\{A, B, C\}$  under the new set  $F''$ :

- **Initialization:**  $result = \{A, B, C\}$
- **First Iteration:**
  - Check  $\{A, B, C\} \rightarrow \{D\}$ : Since  $\{A, B, C\} \subseteq result$ , we add  $D$  to  $result$ . Now,  $result = \{A, B, C, D\}$ .
  - Check  $\{D\} \rightarrow \{A, B\}$ : Since  $D \subseteq result$ , we add  $A$  and  $B$ , but they are already in  $result$ .
  - Check  $\{E\} \rightarrow \{A, C\}$ : This doesn't apply because  $E \notin result$ .

After the first iteration,  $result = \{A, B, C, D\}$ .

- **Second Iteration:** No further changes occur, so the closure stabilizes at  $\{A, B, C, D\}$ .

Thus,  $\{A, B, C\}^+ = \{A, B, C, D\}$ .

step-3-compare-closure-result-with-ee

**Step 3: Compare Closure Result with  $EE$**

Since  $\{A, B, C\}^+ = \{A, B, C, D\}$  does **not** contain  $EE$ , it means that  $EE$  is **not** in  $\{A, B, C\}^+ \{A, B, C\}^+$ .

conclusion-2

**Conclusion:**

According to the definition,  $EE$  is **not extraneous** in the right-hand side  $\{A, B, C\} \rightarrow \{D, E\}$ .  
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