School of Engineering and Computer Science

SWEN304 **Database System Engineering**

Assignment 3

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Due date: 23:59, Monday 28 May

Submission instructions:

- Submit your assignment in **pdf** via the submission system
- Please make sure to write your **student ID and Name** on your assignment. Assignments without IDs and names will incur a delay of marking.

Question 1. Functional Dependencies and Normal Forms [20 marks]

a) **[4 marks]** Consider a relation schema *N (R, F)* where $R = \{A, B, C\}$. Suppose we find the following two tuples in an instance of this relation schema.

A	*B*	*C*
1	*2*	*3*
4	*2*	*3*

Which of the following functional dependencies do definitely **not** hold over the relation schema *N*? Justify your answer.

1) $C \rightarrow A$***, Does not hold as each value of C is mapped to more than 1 value of A, i.e 3 is mapped to both 1 & 4, which means that the functional dependency does not hold.***
2) $A \rightarrow C$***, no issue****.*
3) $B \rightarrow A$***, Does not hold as each value of B is mapped to more than 1 value of A, i.e 2 is mapped to both 1 & 4, which means that the functional dependency does not hold.***
4) $B \rightarrow C$***, no issue***

b) **[16 marks]** Consider a relation schema *N* (*R*, *F*) where $R = \{A, B, C, D\}$. For each of the following sets *F* of functional dependencies, determine which normal form (1NF, 2NF, 3NF, BCNF) the relation schema *N* is in. Justify your answer.

Hint: Note that in all four cases *AB* is the only key for *N*.

1) $F = \{AB \rightarrow C, C \rightarrow D\}$**, 2nd normal form as transitive dependency still remains**
2) $F = \{AB \rightarrow D, B \rightarrow C\}$, **1st normal form as B -> C which is a partial dependency as B is apart of the candidate key and is determining a none prime attribute C.**
3) $F = \{AB \rightarrow C, AB \rightarrow D\}$, **Boyce-Codd normal form as all dependencies have super keys associated with them.**

4) $F = \{AB \rightarrow CD, C \rightarrow B\}$, **3rd normal form as no transitive dependencies but also not all dependencies have super keys associated with them**

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Question 2. Candidate Key **[5 marks]**

Consider a relation schema $N(R, F)$ where $R=\{A, B, C, D, E\}$ with the set of functional dependencies

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

Is AB a candidate key of this relation? If not, is ABD? Explain your answer.

Question 2

- Attributes that are not found on RHS of any functional dependency definitions will be a part of the candidate key.

$F=\{AB \rightarrow C, CD \rightarrow E, DE \rightarrow B\}$, $R(ABCDE)$

- $(AD)^+ = \{A, D\}$, AD must be in candidate key.
- $(ADB)^+ = \{A, D, B, C, E\}$ $\therefore$ candidate key
- $(ADC)^+ = \{A, D, C, \cancel{B}E, B\}$, $\therefore$ candidate key
- $(ADE)^+ = \{A, D, E, B, C\}$ $\therefore$ candidate key
- As $\{AB\}$ does not contain D it will not be a candidate key, proving this:
$(AB)^+ = \{A, B, C\} \neq$ candidate key.

Question 3. Minimal Cover of a set of Functional Dependencies **[20 marks]**

Consider the set of functional dependencies $F = \{A \rightarrow B, B \rightarrow C, CD \rightarrow A, AC \rightarrow D\}$. Compute a minimal cover of F. Justify your answer.

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

1) All RHS are singleton

2) $CD \to A$, $C^+ = \{C\}$, $D^+ = \{D\}$, no issue
$AC \to D$, $A^+ = \{A, B, C, D\}$, $\therefore$ $AC \to D$ becomes $A \to D$
$\therefore F = \{A \to B,\ B \to C,\ CD \to A,\ A \to D\}$

3) $A \to B$, $A^+ = \{A, D\}$
$B \to C$, $B^+ = \{B\}$
$CD \to A$, $C^+ = \{C\}$, $D^+ = \{D\}$
$A \to D$, $A^+ = \{A, B, C\}$, $D^+ = \{D\}$
No redundant dependencies.

$\therefore F_{min} = \{A \to B,\ B \to C,\ CD \to A,\ A \to D\}$

Question 4. Normalization

Note: I am assuming that identifying all keys, means to identify all minimal candidate keys, as the entire relation could be a key or any set of attributes can be a key as long as it contains the minimal key attributes.

[55 marks]

a) **[15 marks]** Consider a relation schema $N(R, F)$ where $R = \{A, B, C, D\}$ and $F = \{B \to C, CD \to A, B \to D\}$. Perform the following tasks. Justify your answers.

1) Identify all keys for N. Show your process. **B is the only key as it determines all other values. B+: {B, C, D, A} therefore key. CD = C+: {C} & D+: {D} therefore not a key.**

2) Identify the highest normal form (1NF, 2NF, 3NF, BCNF) that N satisfies. **1st normal form as partial dependency as B -> (C & D) -> A therefore B -> A therefore partial dependency as A is not a prime.**

3) If N is not in 3NF, compute a lossless transformation into a set of 3NF relation schemas that preserve attributes and functional dependencies.

3) F = {B -> C, CD -> A, B -> D}

CD -> A, $C^+ = \{C\}$ $D^+ = \{D\}$ ∴ no issue
B -> C, $B^+ = \{B, D\}$
B -> D, $B^+ = \{B, C\}$

∴ $F_{minimal} = F$

Decomposition: Combining keys

$R_1 = (\underline{B}, C)$ ⟶ S($\underline{B}$, C, D), (B)
$R_2 = (\underline{CD}\, A)$ ⟶ T($\underline{C, D}$, A), (C,D)
$R_3 = (\underline{B}\, D)$ ⟶ P($\underline{B}$), (B)

∴ Decomposition = {({B,C,D}, {B}), ({C,D,A}, {CD}), ({B}, {B})}

- If each attribute in all functional dependencies appears in the decomposition, then the are preserved. B -> C is in S(B,C,D), CD -> A is in T(CD,A) & B -> D is in S(B,C,D), ∴ all dependencies are preserved.

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	A	B	C	D
T	a		a	a
P		a	a	a
S	a	a	a	a

, Table of decomposition shows that as 1 row is fulled by a, it shows that our decomposition is lossless. Also applying the synthesis garentee's a 3rd normal form result.

The image also shows q4.

b) [15 marks] Consider a relation schema $N(R, F)$ where $R = \{A, B, C, D\}$ and $F = \{A \rightarrow B, C \rightarrow D\}$. Perform the following tasks. Justify your answers.

1) Identify all keys for *N*. Show your process. **AC is the only key as it determines all other values. A+: {B } & C+: {D} therefore AC is key.**

2) Identify the highest normal form (1NF, 2NF, 3NF, BCNF) that *N* satisfies.

1NF as AC is partially dependent due to A -> B and C -> D.

3) If *N* is not in 3NF, compute a lossless transformation into a set of 3NF relation schemas that preserve attributes and functional dependencies.

3) $F = \{A \rightarrow B, C \rightarrow D\}$
$A \rightarrow B$, $A^+ = \{B\}$
$C \rightarrow D$, $C^+ = \{C\}$
$\therefore F_{minimal} = F$

Decomposition: combining keys: & PK addition

$R_1 = (A, B), (A)$ $\longrightarrow$ $P = (A, B), (A)$
$R_2 = (C, D), (C)$ $\quad\quad\quad\;\;$ $S = (C, D), (C)$
$K = (A, C), (AC)$

$\therefore$ Decomposition $= \{(\{A, B\}, \{A\}), (\{C, D\}, \{C\}), (\{A, C\}, \{AC\})\}$

4 If each attribute in all dependencies is in decomposition, then all are preserved: $A \rightarrow B$ in $P(A, B)$ & $C \rightarrow D$ in $S(C, D)$
$\therefore$ all dependencies preserved.

	A	B	C	D
P	a	a		
S			a	a
K	a	a	a	a

, Table shows that as 1 row is filled by a, alpha, the decomposition is lossless.
Also applying the synthesis, a 3rd normal form output is garenteed.

Image also shows q4.

c) [25 marks] Consider a relation schema $N(R, F)$, where $R = \{A, B, C, D\}$ and $F = \{A \rightarrow C, D \rightarrow B, BC \rightarrow A, BC \rightarrow D\}$. Perform the following tasks. Justify your answers.

$F = \{A \to C,\ D \to B,\ BC \to A,\ BC \to D\}$, $R(A, B, C, D)$

1 Keys =

- $(A)^+ = \{A, C\}$ - $(BC)^+ = \{B, C, A, D\}$ ✓ - $(DA)^+ = \{A, D, C, B\}$ ✓

- $(DC)^+ = \{D, C, B, A\}$ ✓ - $(A, B)^+ = \{A, B, C, D\}$ ✓

∴ Keys = $\{BC, DA, DC, AB\}$, Prime = $\{ABCD\}$

2 1st NF ✓ as no composite att's

2nd NF ✓ as candidate key do not ref non-prime att's,

3rd NF ✓ as all att's are prime & no transitivity.

3 $F = \{A \to C, D \to B, BC \to A, BC \to D\}$
$F_{min} = \{A \to C,\ D \to B,\ BC \to A,\ BC \to D\}$

BC → A, D but not sure if you can do this? Should make no difference.

Decomposition:

$R_1 = (A, C), (A)$
$R_2 = (D, B), (D)$
$R_3 = (B, C, A), (BC)$
$R_4 = (B, C, D), (BC)$

→

$S(A, C), (A)$
$T(D, B), (D)$
$U(B, C, A, D), (BC)$

∴ Decomposition = $\{(\{A, C\}, \{A\}), (\{D, B\}, \{D\}), (\{B, C, A, D\}, \{BC\})\}$

4 If each att in all dependencies appears, then all dependencies are preserved. $A \to C$ in S, $D \to B$ in T, $BC \to A$ in U & $BC \to D$ in U ∴ preserved.

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	A	B	C	D
S	a		a	
T		a		a
U	a	a	a	a

Table shows that as 1 row filled by a, alpha, the decomposition is lossless. Also applying synthesis, 3rd normal form is garenteed.

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