CS 348 - Homework 4

Normal Forms
(100 points)

Fall 2019

Due on:

Note: There will be a 10% penalty for each late calendar day. After five calendar days, the homework will not be accepted.

1. (15 pts) Consider the relation Employee(Ssn, Ename, Pnumber, Plocation, Hours) and following dependencies:

   Ssn → Ename
   Hours, Pnumber → Ename, Plocation
   Plocation, Pnumber → Hours

   a. Which is/are the candidate key(s)? (Select all that apply)
      A. Ename, Ssn
      B. Hours, Plocation, Pnumber
      C. Ename, Plocation, Ssn
      D. Hours, Pnumber, Ssn
      E. Plocation, Pnumber, Ssn

   b. What is the highest normal form in this relation? Justify your answer.
      A. 1NF
      B. 2NF
      C. 3NF
      D. BCNF

> **Solution:** None prime attribute Ename is not fully depended on primary key. Ssn → Ename and Hours, Pnumber → Ename are partial dependencies.

2. (15 pts) Explain the three update anomalies clearly. Please use examples to support your explanation.

Solution: Consider a relation that combines student, instructor, class and registration.
1. Insertion Anomaly: Cannot insert a new class unless a student is assigned to.
2. Update Anomaly: If the instructor of one specific course is changed, all tuples with that course need to be updated.
3. Deletion Anomaly: If a course is canceled, students who registered only that course would also be removed from this relation.

3. (20 pts) Consider the relation

$$\mathbf{R} = \{\text{A, B, C, D, E, F, G, H, I ,G , K}\}$$

with following dependencies:

$$\begin{gathered} \text{AB} \rightarrow \text{CD} \\ \text{D} \rightarrow \text{A} \\ \text{A} \rightarrow \text{E} \\ \text{FG} \rightarrow \text{CH} \\ \text{I} \rightarrow \text{JK} \\ \text{K} \rightarrow \text{BE} \end{gathered}$$

a. Identify the candidate key. Show your work.

Solution: 1. Attributes that on neither side: none
2. Attributes only on right side: C, E, H, J, K
3. Attributes only on left side: F, G, I
4. Attributes on both sides: A, B, D, K
5. Combine 1. and 3. we get FGI. And $\{FGI\}^+ = \{\text{B, C, E, F, G, H, I, J, K}\} \neq \text{R}$
6. Consider the relation exterior from 4. $\{AFGI\}^+ = \text{R}$. $\{DFGI\}^+ = \text{R}$
6. Candidate keys are **{AFGI, DFGI}**

b. If applicable, find decomposition of R into 3NF and BCNF.

Solution: 3NF:
1. AB $\rightarrow$ CD violates 3NF. $\{AB\}^+$={A, B, C, D, E}. Decompose R into R1(A, B, C, D, E) and R2(A, B, F, G, H, I, J, K).
2. In R1, A $\rightarrow$ E violates 3NF. $\{A\}^+$={A, E}. Decompose R1 into R11(A, E) and R12(A, B, C, D). R11, R12 satisfy 3NF.

3. In R2, FG $\rightarrow$ CH violates 3NF. $\{FG\}^+$={F, G, H}. Decompose R2 into R21(F, G, H) and R22(A, B, F, G, I, J, K). R21 satisfies 3NF.
4. In R22, I $\rightarrow$ JK violates 3NF. $\{I\}^+$={I, J, K, B}. Decompose R22 into R221(I, J, K, B) and R222(A, F, G, I).R222 satisfies 3NF.
5. In R221, K $\rightarrow$ B violates 3NF. $\{K\}^+$={K, B}. Decompose R221 into R2211(K, B) and R2212(I, J, K). R2211, R2212 satisfy 3NF.
The decomposition of R into 3NF is:
R11(A, E)
R12(A, B, C, D)
R21(F, G, H)
R2211(K, B)
R2212(I, J, K)
R222(A, F, G, I)
BCNF:
In R12, D $\rightarrow$ A violates BCNF. Decompose R12 into R121(D, A) and R122(B, C, D). R121, R122 satisfy BCNF.
The decomposition of R into BCNF is:
R11(A, E)
R121(D, A)
R122(B, C, D)
R21(F, G, H)
R2211(K, B)
R2212(I, J, K)
R222(A, F, G, I)

4. (30 pts) Given the relation R and the set of functional dependencies S as below:

$$\text{R} = \{\text{A, B, C, D, W, X, Y, Z}\}$$
$$\text{S:}$$
$$\text{A} \rightarrow \text{B}$$
$$\text{ABCD} \rightarrow \text{W}$$
$$\text{WX} \rightarrow \text{YZ}$$
$$\text{ACDX} \rightarrow \text{WY}$$

a. Identify the candidate key. Show your work.

Solution: 1. Attributes on neither side: none
2. Attributes only on left: A, C, D, X
3. Attributes only on right: Y, Z
4. Combine 1. and 3. we get A, C, D, X. $\{A, C, D, X\}^+ = R$
So ACDX is the candidate key.

b. What is the minimum cover for the set of functional dependencies S?

Solution: 1. Split the dependencies into:
A $\rightarrow$ B
ABCD $\rightarrow$ W
WX $\rightarrow$ Y
WX $\rightarrow$ Z
ACDX $\rightarrow$ W
ACDX $\rightarrow$ Y
2. Since A $\rightarrow$ B, ACD $\rightarrow$ ABCD $\rightarrow$ W, replace second dependency as ACD $\rightarrow$ W
3. Since ACD $\rightarrow$ W, replace ACDX $\rightarrow$ W with ACD $\rightarrow$ W
4. Since ACD $\rightarrow$ W, WX $\rightarrow$ ACDX $\rightarrow$ Y, we can remove the last dependency.
5. The result would be
A $\rightarrow$ B
ACD $\rightarrow$ W
WX $\rightarrow$ Y
WX $\rightarrow$ Z

c. Find the decomposition of R into 3NF relations that is lossless-join and dependency preserving. Show your work.

Solution: 1. Since the candidate key is ACDX, we can see that A $\rightarrow$ B is a partial dependency.
2. By separating this dependency we can get $R_1 = \{A, B\}$
and $R_2 = \{A, C, D, W, X, Y, Z\}$

3. WX $\rightarrow$ YZ violates in R_2, so further decompose into $R_{21} = \{W, X, Y, Z\}$ and $R_{22} = \{A, C, D, W, X\}$
4. ACD $\rightarrow$ W violates in R_{22}, further decompose into $R_{221} = \{A, C, D, W\}$ and $R_{222} = \{A, C, D, X\}$
5. This also satisfies 3NF.
6. So the decomposition would be
$R_1 = \{A, B\}$
$R_{21} = \{W, X, Y, Z\}$
$R_{221} = \{A, C, D, W\}$
$R_{222} = \{A, C, D, X\}$

5. (20 pts) Consider the relation R and the set of functional dependencies S:

$$\text{R} = \{\text{X, Y, Z, M, N}\}$$
$$\text{S:}$$
$$\text{XY} \rightarrow \text{Z}$$
$$\text{ZM} \rightarrow \text{N}$$
$$\text{Y} \rightarrow \text{M}$$
$$\text{Z} \rightarrow \text{X}$$

$$R_1 = \{X, Y, Z\}$$
$$R_2 = \{X, Z, M, N\}$$
$$R_3 = \{Y, M\}$$

a. Explain why or why not this decomposition is a lossless-join decomposition.

Solution: Original S table:

	X	Y	Z	M	N
R1	a	a	a	b	b
R2	a	b	a	a	a
R3	b	a	b	a	b

After applying Y $\rightarrow$ M, ZM $\rightarrow$ N:

	X	Y	Z	M	N
R1	a	a	a	a	a
R2	a	b	a	a	a
R3	b	a	b	a	b

So this decomposition is lossless-join decomposition.

b. Explain why or why not this decomposition is dependency preserving.

Solution: All functional dependencies are preserved in this decomposition.