CARNEGIE MELLON UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE
15-445/645 – DATABASE SYSTEMS (FALL 2017)
PROF. ANDY PAVLO

Homework 2 (by Prashasthi Prabhakar) – Solutions

Due: **Wednesday Sep 20, 2017 @ 11:59pm**

IMPORTANT:

- **Upload a PDF** of your answers to **Gradescope by 11:59pm on Wednesday Sep 20, 2017**.
- **Plagiarism**: Homework may be discussed with other students, but all homework is to be completed **individually**.
- **Typeset** all your answers.

For your information:

- Graded out of **100** points; **4** questions total
- Rough time estimate: ≈1-4 hours (0.5-1 hours for each question)

Revision : 2017/10/22 09:40

Question	Points	Score
Functional Dependencies I	15	
Functional Dependencies II	32	
Decompositions	20	
Normal Forms	33	
Total:	100	

Question 1: Functional Dependencies I . . . . . [15 points]

GRADED BY: Mengran

Consider the following legal instance of a relational schema S with attributes XYZ:

S	X	Y	Z
	m	20	T
	m	10	F
	o	30	T
	n	30	T
	o	20	T

Table 1: Legal instance of schema S for question 2.1

(a) Which of the following dependencies are *violated* by the instances of S in Table 1?

i. **[2 points]** ■ **Yes** □ No : $X \rightarrow Y$ is violated.

ii. **[2 points]** ■ **Yes** □ No : $Z \rightarrow X$ is violated.

iii. **[2 points]** □ Yes ■ **No** : $Y \rightarrow Z$ is violated.

iv. **[2 points]** □ Yes ■ **No** : $XY \rightarrow Z$ is violated.

v. **[2 points]** ■ **Yes** □ No : $YZ \rightarrow X$ is violated.

vi. **[2 points]** ■ **Yes** □ No : $XZ \rightarrow Y$ is violated.

(b) **[3 points]** By only observing the instance of S in Table 1, can you identify the functional dependencies that hold on schema S? Why?

□ Yes ■ **No**

Solution: No, because we can only see an instance.

Question 2: Functional Dependencies II . . . . . [32 points]

GRADED BY: Allison

For the next set of questions consider the relational schema $\mathcal{R} = \{P, Q, R, S, T, U, V, W\}$ and the set of functional dependencies FD:

$$Q \rightarrow U \quad (1)$$
$$U \rightarrow V \quad (2)$$
$$PQ \rightarrow WST \quad (3)$$
$$SU \rightarrow TR \quad (4)$$
$$VT \rightarrow RW \quad (5)$$
$$R \rightarrow W \quad (6)$$

(a) **[8 points]** Which of the following is a minimum cover of the FD? Mark all that qualify; if none, mark accordingly, and give your *own*. answer.

i. The given FDs (Eq 1-6), is a minimum cover already.
ii. $\{Q \rightarrow U, U \rightarrow V, PQ \rightarrow S, SU \rightarrow T, SU \rightarrow R, VT \rightarrow R, VT \rightarrow W, R \rightarrow W\}$
iii. $\{Q \rightarrow U, U \rightarrow V, PQ \rightarrow S, SU \rightarrow T, PQ \rightarrow W, VT \rightarrow R, PQ \rightarrow T, R \rightarrow W\}$
iv. $\{Q \rightarrow U, U \rightarrow V, PQ \rightarrow S, SU \rightarrow T, VT \rightarrow R, R \rightarrow W\}$
v. $\{Q \rightarrow U, U \rightarrow V, PQ \rightarrow S, SU \rightarrow T, SU \rightarrow R, VT \rightarrow R, PQ \rightarrow T, R \rightarrow W\}$
vi. none of the above - the cover is _____

Solution: iv

(b) Yes/No: Which of the following functional dependencies can be deduced, from the above set of functional dependencies (Eq. (1)-(6))?

i. **[3 points]** ■ **Yes** □ No : $Q \rightarrow V$
ii. **[3 points]** □ Yes ■ **No** : $QU \rightarrow R$
iii. **[3 points]** ■ **Yes** □ No : $SQ \rightarrow T$
iv. **[3 points]** ■ **Yes** □ No : $SQ \rightarrow W$
v. **[3 points]** ■ **Yes** □ No : $PQ \rightarrow R$
vi. **[3 points]** □ Yes ■ **No** : $VT \rightarrow Q$

(c) **[3 points]** True or False: The attribute closure $\{Q\}^+$ is $\{Q, U, V\}$.

■ **True** □ False

(d) **[3 points]** True or False: The attribute closure $\{PQ\}^+$ is $\{P, Q, W, S, T\}$.

□ True ■ **False**

Grading info: *It is* $\{P, Q, R, S, T, U, V, W\}$.

Question 3: Decompositions.....[20 points]

GRADED BY: Prashasthi

For this set of questions, consider the relation with attributes, $\mathcal{X} = \{A, B, C, D, E, F\}$, Let the following functional dependencies FD be defined over the relation $\mathcal{X}$:

$$A \rightarrow B$$
$$B \rightarrow CD$$
$$E \rightarrow F$$

(a) **[2 points]** Provide the attribute closure of $\{AB\}$.

Solution: $\{AB\}^+ = \{ABCD\}$

(b) Consider the decomposition AB, BCD, EF. Mark 'True' or 'False':

i. **[3 points]** ☐ True ■ **False** : It is lossless

ii. **[3 points]** ■ **True** ☐ False : It is dependency-preserving

(c) Consider the decomposition AB, $BCDF$, EF. Mark 'True' or 'False':

i. **[3 points]** ☐ True ■ **False** : It is lossless

ii. **[3 points]** ■ **True** ☐ False : It is dependency-preserving

(d) Consider the decomposition $ABCEF$, EBD. Mark 'True' or 'False':

i. **[3 points]** ■ **True** ☐ False : It is lossless

ii. **[3 points]** ■ **True** ☐ False : It is dependency-preserving

Question 4: Normal Forms.....[33 points]

GRADED BY: Leon

Consider the relation with attributes, $\mathcal{E} = \{P, Q, R, S\}$. Suppose that the following functional dependencies hold:

$$PQ \rightarrow R \quad (7)$$
$$PQ \rightarrow S \quad (8)$$
$$R \rightarrow P \quad (9)$$
$$S \rightarrow Q \quad (10)$$

(a) **[6 points]** List *all* the candidate key(s) for $\mathcal{E}$.

Solution: $\{PQ\}, \{QR\}, \{RS\}, \{PS\}$

Grading info: -2: for each missing candidate key

(b) **[2 points]** Is the relation $\mathcal{E}$ in BCNF? □ Yes ■ **No**

(c) From the list below, select all applicable choices to justify whether $\mathcal{E}$ is (or is not) in BCNF.

Note: when we refer to the *main requirement* for BCNF, we mean: *every determinant is a super key*.

i. **[1 point]** □ True ■ **False** : All FD's satisfy the main requirement.
ii. **[1 point]** □ True ■ **False** : FD (7) violates the main requirement.
iii. **[1 point]** □ True ■ **False** : FD (8) violates the main requirement.
iv. **[1 point]** ■ **True** □ False : FD (9) violates the main requirement.
v. **[1 point]** ■ **True** □ False : FD (10) violates the main requirement.

(d) **[2 points]** Is the relation $\mathcal{E}$ in 3NF? ■ **Yes** □ No

(e) From the list below, select all applicable choices to justify whether $\mathcal{E}$ is (or is not) in 3NF.

Note: when we refer to the *secondary requirement* for 3NF, we mean: *for every FD $X \rightarrow A$, A is part of a candidate key*.

i. **[1 point]** ■ **True** □ False : All FD's satisfy the secondary requirement.
ii. **[1 point]** □ True ■ **False** : FD (7) violates the secondary requirement.
iii. **[1 point]** □ True ■ **False** : FD (8) violates the secondary requirement.
iv. **[1 point]** □ True ■ **False** : FD (9) violates the secondary requirement.
v. **[1 point]** □ True ■ **False** : FD (10) violates the secondary requirement.

(f) **[5 points]** Give a 3NF decomposition of $\mathcal{E}$ that is lossless, dependency preserving, and has as few tables as possible.

Solution: $\mathcal{E}_{1,1}$=(P, Q, R, S)

Grading info: -1: 3NF decomposition with 2 tables; -3: 3NF decomposition more than with 2 tables; -4: 3NF decomposition with more than 5 tables

(g) **[8 points]** Give a BCNF decomposition of $\mathcal{E}$ that is lossless, and has as few tables as possible.

Solution: $\mathcal{E}_{1,1}$=(P, R), $\mathcal{E}_{1,2}$=(Q, S), $\mathcal{E}_{1,3}$=(R, S)

Grading info: -5: BCNF decomposition with more than 3 tables