BSCCS2001: Practice with Solutions
Week 6

1. Consider the relational schema $\mathbf{R}(A, B, C, D, E)$, where the domains of A, B, C, D and E include only atomic values. Identify the possible set of functional dependencies that $\mathbf{R}$ can have such that $\mathbf{R}$ is in BCNF.

[MSQ: 2 points]

- √ FD: $\{AB \to CDE\}$
- ◯ FD: $\{AB \to CD, B \to E\}$
- ◯ FD: $\{AB \to CD, C \to D, D \to E\}$
- ◯ FD: $\{AB \to CDE, D \to A, E \to B\}$

Solution: Given that in $\mathbf{R}$ each attribute is a single-valued attribute. Thus $\mathbf{R}$ is already in 1NF.
Option-1: FD: $\{AB \to CDE\}$
The only candidate key (thus primary key) is: AB as $(AB)^+ = \{ABCDE\}$.
As all the non-prime attributes are fully functionally dependent on the candidate key, it is already in 2NF.
$\{AB \to CDE\}$, where AB is a superkey. Thus, **it is in 3NF and also in BCNF**.
Option-2: $\{AB \to CD, B \to E\}$
The only candidate key (thus primary key) is: AB as $(AB)^+ = \{ABCDE\}$.
$B \to E$ is a partial functional dependency. Thus, it is in 1NF but not in 2NF.
Option-3: FD: $\{AB \to CD, C \to D, D \to E\}$
The only candidate key (thus primary key) is: AB as $(AB)^+ = \{ABCDE\}$.
There is no partial functional dependency. Thus, it is already in 2NF.
$AB \to CD$, where AB is superkey.
But, for $C \to D$, $D \to E$

- the functional dependencies are not trivial.
- L.H.S of the functional dependencies are not superkeys.
- R.H.S of the functional dependencies are not prime attributes.

Thus, these two FDs violate 3NF rules. So, $\mathbf{R}$ is in 2NF but not in 3NF based on this set of FDs.
Option-4: FD: $\{AB \to CDE, D \to A, E \to B\}$
The candidate keys are: AB and DE as $(AB)^+ = \{ABCDE\}$ and $(DE)^+ = \{ABCDE\}$. The prime attributes are A, B, D, E.
There is no partial functional dependency. Thus, it is already in 2NF.
$AB \to CDE$, where AB is superkey.
For $D \to A$, $E \to B$ R.H.S of the functional dependencies are prime attributes. Thus, it is in 3NF. However, These two FDs do not satisfy BCNF (as L.H.S are not superkeys). So, $\mathbf{R}$ is in 3NF but not in BCNF based on this set of FDs.

2. Consider the relational schema $\mathbf{R}(A, B, C, D, E, F)$, where the domains for A, B, C, D, E and F include atomic values only. If $\mathbf{R}$ satisfies the functional dependencies $\{AB \rightarrow CDE, E \rightarrow F, BF \rightarrow A, C \rightarrow B\}$, then identify the correct statement(s).

[MSQ: 2 points]

- ○ $\mathbf{R}$ is in 1NF but not in 2NF
- √ $\mathbf{R}$ is in 2NF and also in 3NF
- √ $\mathbf{R}$ is in 3NF but not in BCNF
- ○ $\mathbf{R}$ is in 3NF also in BCNF

Solution:
Candidate keys are: AB, BF, AC, BE, CF and CE. So, prime attributes are: A, B, C, E and F. For the FDs: $E \rightarrow F$ and $C \rightarrow B$, B and F are prime attributes. Thus, there is no partial dependency, thus R is in 2NF.
$AB \rightarrow CDE$ and $BF \rightarrow A$, as AB and BF both are candidate keys, the FDs are in 3NF.
$C \rightarrow B$ and $E \rightarrow F$ also in 3NF, since B and F are prime attributes. Thus, R is in 3NF.
$C \rightarrow B$ and $E \rightarrow F$ violate BCNF conditions as C and E are not superkeys. Thus, R is not in BCNF.

3. Consider the relational schema **Z**(P, Q, R, S) and the following functional dependencies on **Z**. [MCQ: 2 points]

- $P \rightarrow QRS$
- $Q \rightarrow R$
- $RS \rightarrow P$

Which of the following is/are correct?

○ **Z** is in 3NF and also in BCNF

√ **Z** is in 3NF but not in BCNF

○ **Z** is in 2NF but not in 3NF

○ **Z** is in BCNF but not in 3NF

Solution: FD = $\{P \rightarrow QRS,\ Q \rightarrow R,\ RS \rightarrow P\}$
$P^+ = PQRS$
$RS^+ = PQRS$
$QS^+ = PQRS$
So, candidate keys are P, QS & RS and prime attribute are P, Q, R & S.
Since the schema **Z** has no partial dependencies or transitive dependencies, so it is in 3NF.

Check for BCNF
$P \rightarrow QRS$ (P is candidate key) ✓
$Q \rightarrow R$ (Q is not candidate key) ×
$RS \rightarrow P$ (RS is candidate key) ✓

So, **Z** is in 3NF but not in BCNF.

4. Let $\mathbf{R}(P,Q,R,S,T,U,V,W)$ be a relation (all attributes have atomic values only) with the following functional dependencies:

   - $\{PQ \rightarrow RSTU\}$
   - $\{P \rightarrow R\}$
   - $\{Q \rightarrow S\}$
   - $\{R \rightarrow UV\}$
   - $\{V \rightarrow W\}$
   - $\{W \rightarrow U\}$
   - $\{V \rightarrow U\}$

   Find the highest normal form in which the relation $\mathbf{R}$ is in.

   [MCQ: 2 points]

   √ 1NF
   ◯ 2NF
   ◯ 3NF
   ◯ BCNF

Solution: Since all attributes in $\mathbf{R}$ have atomic values, it follows that $\mathbf{R}$ is in 1NF.

In order to check if $\mathbf{R}$ is in 2NF, we must find the candidate keys. Using the given FDs, we find that PQV is the only candidate key. Hence P, Q and V are the prime attributes and the rest are non-prime.
Now due to the presence of partial dependency, the relation $\mathbf{R}$ is not in 2NF.

Note: Partial dependency occurs when a non-prime attribute is functionally dependent on a subset of a candidate key.

5. Consider the instance of relation **Course** given in Figure 1. [MSQ: 2 points]

course_name	instructor	book	edition
DBMS	Geeta	DBMS-Beginner	3
DBMS	Arjun	DBMS-Beginner	3
DBMS	Geeta	DBMS-Expert	2
DBMS	Arjun	DBMS-Expert	2
Java	Rahul	Java-Beginner	5
Java	Rahul	Java-Intermediate	3
Java	Rahul	Java-Expert	4
Java	Armaan	Java-Beginner	5
Java	Armaan	Java-Intermediate	3
Java	Armaan	Java-Expert	4

Figure 1: An instance of relation **Course**

Which among the following multivalued dependencies can be inferred from the given information?

$\surd$ $course\_name \rightarrow\rightarrow instructor$

◯ $course\_name \rightarrow\rightarrow book$

◯ $course\_name \rightarrow\rightarrow edition$

$\surd$ $course\_name \rightarrow\rightarrow book, edition$

Solution:
Let us first number the tuples as $t_1, t_2, \cdots, t_{10}$.
Test for $course\_name \rightarrow\rightarrow instructor$**:**
In relation **Course**, there exist two tuples t_1 and t_2 such that
$t_1[course\_name] = t_2[course\_name]$.
We also have two tuples t_3 and t_4 in **Course** with the following properties:

- $t_1[course\_name] = t_2[course\_name] = t_3[course\_name] = t_4[course\_name]$,
- $t_3[instructor] = t_1[instructor]$ and $t_2[instructor] = t_4[instructor]$,
- $t_1[book, edition] = t_2[book, edition]$ and $t_3[book, edition] = t_4[book, edition]$.

Thus it satisfies MVD conditions.
In the relation **Course**, there are three tuples t_5, t_6 and t_7 such that
$t_5[course\_name] = t_6[course\_name] = t_7[course\_name]$.
We also have three tuples t_8, t_9 and t_{10} in **Course** with the following properties:

- $t_5[course\_name] = t_6[course\_name] = t_7[course\_name] = t_8[course\_name] = t_9[course\_name] = t_{10}[course\_name]$,

- $t_5[instructor] = t_6[instructor] = t_7[instructor]$ and $t_8[instructor] = t_9[instructor] = t_{10}[instructor]$,

- $t_5[book, edition] = t_8[instructor, edition]$, $t_6[book, edition] = t_9[instructor, edition]$ and $t_7[book, edition] = t_{10}[book, edition]$.

Thus, MVD conditions are satisfied.
Test for $course\_name \rightarrow\rightarrow book, edition$:
MVD Complementation rule: In a relation R, if $X \rightarrow\rightarrow Y$, then $X \rightarrow\rightarrow R - XY$.
Since we already have $course\_name \rightarrow\rightarrow instructor$, it follows that $course\_name \rightarrow\rightarrow book, edition$ also correct.
If we follow the same procedures as discussed above, we will be able to show that the MVDs:
$course\_name \rightarrow\rightarrow book$
$course\_name \rightarrow\rightarrow edition$
are not satisfied on relation **Course**.

6. Consider the relational schema:
Intern($intern\_code, intern\_name, project, hobby$).
An intern can work in several projects and can have several hobbies. However, it maintains the FD: $intern\_code \rightarrow intern\_name$.
Identify the most appropriate 4NF decomposition for the given schema.

[MCQ: 2 points]

- ○ **R1**($intern\_code, intern\_name, project, hobby$), **R2**($intern\_code, project, hobby$)
- ○ **R1**($intern\_code, intern\_name, project$), **R2**($intern\_code, hobby$)
- ○ **R1**($intern\_code, intern\_name, hobby$), **R2**($intern\_code, project$)
- √ **R1**($intern\_code, intern\_name$), **R2**($intern\_code, project$), **R3**($intern\_code, hobby$)

Solution:
From the given information in the question, $intern\_code$ cannot be a super key for the given relation. Thus, $intern\_code \rightarrow intern\_name$ violates BCNF conditions.
Thus, a possible BCNF decomposition would be:
R1($intern\_code, intern\_name$), where $intern\_code$ is the candidate key, and
R2($intern\_code, project, hobby$).
R2 violates 4NF conditions as it has the following MVDs:
$intern\_code \rightarrow\rightarrow project$, and
$intern\_code \rightarrow\rightarrow hobby$
So the 4NF decomposition is:
R2($intern\_code, project$), and
R3($intern\_code, hobby$).
Thus, the 4NF decomposition is:
R1($intern\_code, intern\_name$),
R2($intern\_code, project$),
R3($intern\_code, hobby$).

7. Let $\mathbf{S}(Y,\ U,\ V)$ be a relation. Let $\mathbf{R}(P,\ W,\ X,\ Y,\ Z)$ be another relation with the following functional dependencies:
$\mathcal{F} = \{X \rightarrow ZW, Y \rightarrow X, W \rightarrow P\}$

R contains 300 tuples and **S** contains 250 tuples. What is the maximum number of tuples possible as output of $\mathbf{R} \bowtie \mathbf{S}$?

[MCQ: 2 point]

- ◯ 75000
- √ 250
- ◯ 300
- ◯ 50

Solution: From the given set of functional dependencies, Y is a candidate key of relation **R**. So all 300 values of Y must be unique in **R**.
There is no functional dependency given for S and to get the maximum number of tuples in output, there can be two possibilities for S.

- All 250 values of Y in **S** are same and there is an entry in **R** that matches with this value. In this case, we get 250 tuples in output.
- All 100 values of Y in **S** are different and these values are present in **R** also. In this case also, we get 250 tuples.

8. Let $\mathbf{A}(T, U, V, W)$ be a relational schema with the following functional dependencies:
$\mathcal{F} = \{W \to UT, UV \to W, V \to T, W \to U\}$
It is given that $\mathbf{A}$ is not in BCNF.
Suppose $\mathbf{A}$ is decomposed into two relational schemas, $\mathbf{B}(TV)$ and $\mathbf{C}(UVW)$.
Which of the following statement(s) is/are correct?

[MSQ: 2 points]

- ◯ Decomposition of schema A into B and C is dependency preserving
- √ Decomposition of schema A into B and C is lossless
- ◯ Both B and C are in BCNF
- √ Relation B is in BCNF

Solution:

- $\mathbf{B}(TV)$ preserves $\{V \to T\}$ and has V as the candidate key. So, relation $\mathbf{B}$ is in BCNF.
- $\mathbf{C}(UVW)$ preserves $\{UV \to W,\ W \to U\}$ and has UV and VW as the candidate keys. So, relation $\mathbf{C}$ is in 3NF but not in BCNF, as W is not a superkey.
- The decomposition of schema $\mathbf{A}$ into two relational schemas, $\mathbf{B}$ and $\mathbf{C}$, does not cover all the functional dependencies of the original relation $\mathbf{A}$. Hence, it is not dependency preserving.
- The decomposition has common attribute (i.e., V) which is superkey of relation $\mathbf{B}(TV)$, so decomposition of $\mathbf{A}$ into $\mathbf{B}$ and $\mathbf{C}$ is lossless join decomposition.

9. Consider the relational schema:
prescription($doctor\_id, doctor\_name, patient\_id, patient\_name, medicine\_id, medicine\_name$), where the domains of all the attributes consist of atomic values. Consider the following FDs for the relation *department*.

[MCQ: 2 points]

- $doctor\_id \rightarrow doctor\_name$,
- $patient\_id \rightarrow patient\_name$,
- $medicine\_id \rightarrow medicine\_name$,
- $doctor\_id \rightarrow\rightarrow patient\_id$,
- $doctor\_id \rightarrow\rightarrow medicine\_id$

From among the decompositions given, identify the one that is in 4NF.

○ $(doctor\_id, doctor\_name)$,
$(patient\_id, patient\_name)$,
$(medicine\_id, medicine\_name)$,

○ $(doctor\_id, doctor\_name)$,
$(patient\_id, patient\_name)$,
$(medicine\_id, medicine\_name)$,
$(doctor\_id, patient\_id, medicine\_id)$

○ $(doctor\_id, doctor\_name, patient\_id, patient\_name)$,
$(doctor\_id, doctor\_name, medicine\_id, medicine\_name)$

√ $(doctor\_id, doctor\_name)$,
$(patient\_id, patient\_name)$,
$(medicine\_id, medicine\_name)$,
$(doctor\_id, patient\_id)$,
$(doctor\_id, medicine\_id)$

Solution: For the given relation, the candidate key is $\{doctor\_id, patient\_id, medicine\_id\}$ and it is in 1NF. However, it is not in 2NF as the FDs:
$doctor\_id \rightarrow doctor\_name$,
$patient\_id \rightarrow patient\_name$,
$medicine\_id \rightarrow medicine\_name$, are partial functional dependencies. Thus, a possible decomposition is:
R1($doctor\_id, doctor\_name$), where $doctor\_id$ is the candidate key,
R2($patient\_id, patient\_name$), where $patient\_id$ is the candidate key,
R3($medicine\_id, medicine\_name$), where $medicine\_id$ is the candidate key,
R4($doctor\_id, patient\_id, medicine\_id$), where $\{doctor\_id, patient\_id, medicine\_id\}$ is the candidate key,
R1, **R2**, **R3** and **R4** are already in 3NF and BCNF.

R1, **R2** and **R3** are already in 4NF. The MVDs,
$doctor\_id \rightarrow\rightarrow patient\_id$, and
$doctor\_id \rightarrow\rightarrow medicine\_id$ violate 4NF conditions. Thus, **R4** is decomposed as:
R41$(doctor\_id, patient\_id)$ and
R42$(doctor\_id, medicine\_id)$.
Thus, the 4NF decomposition is:
R1$(doctor\_id, doctor\_name)$,
R2$(patient\_id, patient\_name)$,
R3$(medicine\_id, medicine\_name)$
R41$(doctor\_id, patient\_id)$ and
R42$(doctor\_id, medicine\_id)$.

10. Consider the relational schema **R** as:
R(A, B, C, D, E, F, G, H), where the domains of all the attributes consist of atomic values. Consider the following FDs for the relation *department*.

- $A \rightarrow D$,
- $D \rightarrow EF$,
- $BH \rightarrow CG$,
- $G \rightarrow H$,

From among the decompositions given, identify the one that is in BCNF.

[MCQ: 2 points]

○ $(A, D, E, F), (G, H), (B, C, G, H)$ and (A, B, H)
○ $(D, E, F), (A, D), (G, H)$ and (B, C, G)
√ $(D, E, F), (A, D), (G, H), (B, C, G)$ and (A, B, H)
○ $(D, E, F), (A, D), (B, C, G, H)$ and (A, B, H)

Solution: Due to atomic values, the relation **R** is in 1NF.
Candidate key is: ABH as $(ABH)^+ = R$.
Test for 2NF: FD: $A \rightarrow D$ and $BH \rightarrow CG$ violate 2NF conditions (these are partial functional dependencies). Thus, the decomposition of **R** is:
Since $(A)^+ = ADEF$, **R1**(A, D, E, F), where A is the candidate key,
since $(BH)^+ = BHCG$, **R2**(B, H, C, G), where BH is the candidate key, and
R3(A, B, H) consists of the original candidate key of R.
Now, **R1**, **R2** and **R3** are in 2NF.
Test for 3NF: In **R1**, FD $D \rightarrow EF$ violates 3NF conditions (as D is not a superkey). Thus, the decomposition is:
R11(D, E, F), where D is the candidate key and **R12**(A, D), where A is the candidate key.
The relations **R3** and **R2** are already in 3NF (since in **R2**, FD: $G \rightarrow H$ satisfies 3NF conditions as H is a prime attribute).
Test for BCNF: The relations **R11**, **R12** and **R3** are already in BCNF. However, in relation **R2**, FD: $G \rightarrow H$ violates BCNF conditions as G is not a super key). Thus, the decomposition is:
R22(G, H), where G is the candidate key and **R22**(B, C, G), where BCG is the candidate key.
The final relations after decomposition are:
R11(D, E, F), **R12**(A, D), **R21**(G, H), **R22**(B, C, G) and **R3**(A, B, H). Please note that although the decomposition is lossless, it is not dependency preserving.

11. Which of the following statements is/are true regarding temporal relations?

[MSQ: 2 points]

- ◯ A uni-temporal relation can have only valid time.
- ◯ A uni-temporal relation can have only transaction time.
- √ A uni-temporal relation can have either valid transaction time or transaction time.
- √ A bi-temporal relation can have both valid transaction time and transaction time.

Solution:

- An uni-temporal relations has one axis of time, either valid time or transaction time.
- A bi-temporal relation has both axis of time, valid time and transaction time. It includes valid start time, valid end time, transaction start time, transaction end time.