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Introduction to Database Managment 7.5 p
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Exercises, Chapter/Topic 5

Problem 1

a) Canonical Cover

The given relation and functional dependencies are: $R[ABCDEFGH]$, and
$$\mathcal{F}_1 = \{A \to CG,\ ACF \to B,\ B \to F,\ DE \to A,\ DEG \to BF,\ DF \to E,\ G \to A\}$$

1. Decompose each FD into RHS simple form:
   $\{A \to C,\ A \to G,\ ACF \to B,\ B \to F,\ DE \to A,\ DEG \to B,\ DEG \to F,\ DF \to E,\ G \to A\}$

2. LHS-reduce each FD $\{A \to C,\ A \to G,\ ACF \to B,\ B \to F,\ DE \to A,\ DEG \to B,\ DEG \to F,\ DF \to E,\ G \to A\}$
   $= \{A \to C,\ A \to G,\ AF \to B,\ B \to F,\ DE \to A,\ DE \to B,\ DE \to F,\ DF \to E,\ G \to A\}$

3. Test each remaining FD for redundancy of the resulting set of FDs, removing the ones which are not needed to preserve the closure. $\{A \to C,\ A \to G,\ AF \to B,\ B \to F,\ DE \to A,\ DE \to F,\ DF \to E,\ G \to A\}$

   Hence, $\mathcal{F}_{min} = \{A \to C,\ A \to G,\ AF \to B,\ B \to F,\ DE \to A,\ DE \to F,\ DF \to E,\ G \to A\}$

b) find dependency-preserving 3NF representation

1. use the canonical cover from a)

2. define Schemes
   $R_0\{A,C,G\} : A \to C,\ A \to G,\ G \to A$
   $R_1\{A,B,F\} : B \to F,\ AF \to B$
   $R_2\{A,D,E,F\} : DE \to A,\ DE \to F,\ DF \to E$

3. test removing relations
   None of the above relations can be removed.

c) candidate keys

Three candidate keys for R were found: $\{B,D,H\}, \{D,E,H\}, \{D,F,H\}$

d) losless extension

For the losless extension, H needs to be included in some relation. As proposed in c), H is best added to a candidate key. Hence a lossless representation of $\langle R, \mathcal{F}_1 \rangle$ is:
$R_0\{A,C,G\} : A \to C,\ A \to G,\ G \to A$
$R_1\{A,B,F\} : B \to F,\ AF \to B$
$R_2\{A,D,E,F\} : DE \to A,\ DE \to F,\ DF \to E$
$R_3\{B,D,H\}$

e) which relations not BCNF

In a BCNF relational scheme, each functional dependency has to fullfill the following two conditions:
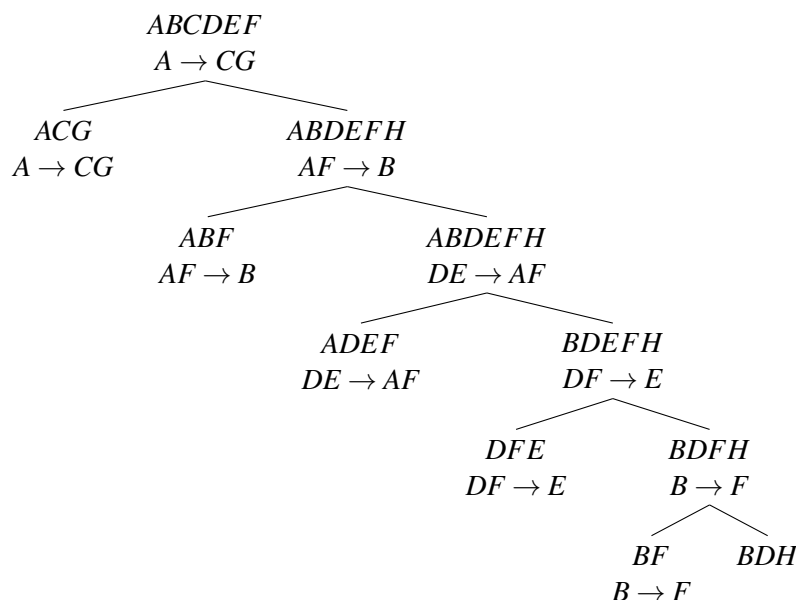
1. $X \to Y$ is a trivial FD $(Y \subseteq X)$

2. X is a super key for the schema R Checking all FD's in d) for those conditions reveals that $R\{A,B,F\}$ is not in BCNF as B is not a super key of $R\{A,B,F\}$. The two above mentioned conditions hold for all the other FDs in all other relations.

f) show that there is no lossless, dependency-preserving, acyclic BCNF possible

This can be proven by showing that there is no dependency-preserving decomposition of the schema $\langle R\{A,F,B\},\ AF \to B,\ B \to F\rangle$ which is in 3NF, computed from the canonical cover. According to the two rules for BCNF decomposition stated in e), $B \to F$ is neither super key nor is it a trivial dependency. So, the only possible lossless decomposition of this schema is $fdepAB$ and $B \to F$, but then the dependency $AF \to B$ is lost.
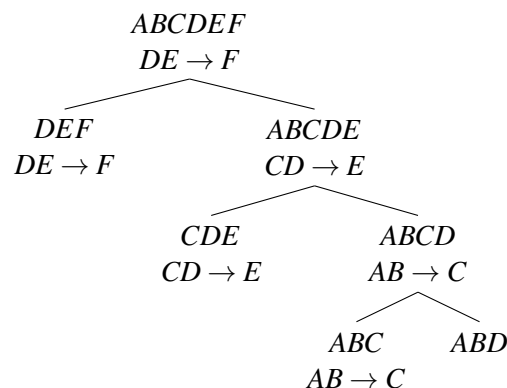
g) Determine whether the 3NF normalization from d) is acyclic/fully independent

No it is not as there is a bottom up join tree construction that represents the full relation R while still not all FD's are used:

```
                    ABCDEF
                    A → CG
              /              \
         ACG              ABDEFH
        A → CG             AF → B
                       /          \
                    ABF          ABDEFH
                   AF → B         DE → AF
                              /           \
                           ADEF          BDEFH
                          DE → AF         DF → E
                                      /          \
                                   DFE          BDFH
                                  DF → E         B → F
                                              /        \
                                            BF         BDH
                                           B → F
```

Problem 2 - BCNF Normalization

Yes can. not cyclic.

```
                    ABCDEF
                    DE → F
               /            \
            DEF            ABCDE
           DE → F          CD → E
                        /          \
                     CDE           ABCD
                    CD → E         AB → C
                                /         \
                             ABC          ABD
                            AB → C
```

Problem 3 - BCNF Normalization

Yes can, but cyclic.