Umeå University
Department of Computing Science

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

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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:

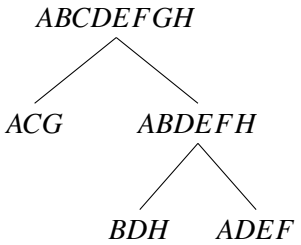
1. $X \to Y$ is a trivial FD $(Y \subseteq X)$
2. X is a super key for the schema R
   Checking all FD's in d) for those conditions reveals that $R\{A,B,F\}$ is not in BCNF as B is not a super key of $R\{A,B,F\}$. The two above mentioned conditions hold for all the other FDs in all other relations.

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 $A \to B$ 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 it is possible to bild the full relation R without using all the sub-relations as shown in the join tree below:

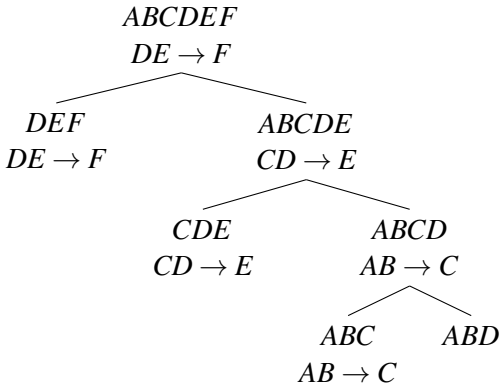


It can be seen that the relation $R\{ABF\}$ was not used.

Problem 2 - BCNF Normalization

First the minimum candidate key(s) where determinded and found to be $\{A,B,D\}$. Now it was attempted to decompose R according to the BCNF algorithm to yield sub relations that adhere to the rules stated in problem 1e. As shown below this was possible, hence the BCNF fulfills the lossless and dependecy-preserving constraint.
$R_0\{A,B,C\} : AB \to C$
$R_1\{C,D,E\} : CD \to E$
$R_2\{D,E,F\} : DE \to F$
$R_3\{A,B,D\}$
Finally, it was determined whether the decomposition is acyclic by constructing a join tree

from bottom up:



All sub-relations where needed to reconstruct the full relation in a bottom up join tree, hence the given database schema is in BCNF, lossless, dependecy-preserving and acyclic.

Problem 3 - BCNF Normalization

Minimum candiate keys were determined, three where found and $\{A, B, D, F\}$ was chosen. Now, BCNF decomposition of the original relation R_3 was attempted by building a join tree and adhering to conditions stated in problem 1e). This however proved to be impossible. Having just three FDs it was here feasibly to exhaustively probe all possible decompositions but none of them yielded a valid, acyclic BCNF decomposition. The problem can be summarized as follows: As the RHS of each FD is part of the LHS for another FD, there can not exist an order of building a valid join tree using all FDs.