CS4416 - Tutorial 4

Normalization

1. Let R(ABCDE) be a relation in Boyce-Codd Normal Form (BCNF). If ABC is the only key for R, describe all the nontrivial functional dependencies that hold for R.

2. Which of the following relations is in Boyce-Codd Normal Form (BCNF)?

a. R(ABCD) FD's: BD → C ; AB → D ; AC → B ; BD → A   yes
b. R(ABCD) FD's: C → B ; BC → A ; A → C ; BD → A   no

3. Which of the following relations is in Third normal form (3NF)?

a. R(ABCD) FD's: ACD → B ; AC → D ; D → C ; AC → B   yes
b. R(ABCD) FD's: ABD → C ; CD → A ; AC → B ; AC → D   yes
c. R(ABCD) FD's: A → B ; B → A ; A → D ; D → B   yes
d. R(ABCD) FD's: AB → C ; ABD → C ; ABC → D ; AC → D   no
e. R(ABCD) FD's: AB → C ; BCD → A ; D → A ; B → C   no
f. R(ABCD) FD's: B → C ; AC → D ; ABD → C ; BCD → A   no
g. R(ABCD) FD's: C → B ; A → B ; CD → A ; BCD → A   no
h. R(ABCD) FD's: C → B ; B → A ; AC → D ; AC → B   no

4. Decompose the following relations into a set of relations in 3NF preserving all FDs.

a. R(ABCD) FD's: AB → C ; ABD → C ; ABC → D ; AC → D
b. R(ABCD) FD's: AB → C ; BCD → A ; D → A ; B → C
c. R(ABCD) FD's: B → C ; AC → D ; AB → D; BD → A
d. R(ABCDE) FD's: D → C, D → E, BC → A, BC → D, BCD → A
e. R(ABCDEF), FD's: B→ F, BCD→ A, C→ D, D→ B, EF→ C, AC → B

Use the **synthesis** algorithm from lecture 8. To find the minimal basis of FD use the following laws for removing FDs and attributes from the LHS of an FD:

1. Reflexivity: if B ⊆ A then A → B
2. Transitivity: if A → B and B → C then A → C
3. Pseudo transitivity: if A → B and BC → D then AC → D
4. Augmentation: if A → B then AC → B

Note: Watch for FDs with the same RHS.

Solutions to Q4:

a. FD Basis: $AB \rightarrow C$; $AC \rightarrow D$

Key: AB

Decomposition:
R1 = {ABC} with $AB \rightarrow C$
R2 = {ACD} with $AC \rightarrow D$

b. FD Basis: $D \rightarrow A$; $B \rightarrow C$

Key: BD

Decomposition:
R1 = {AD} with $A \rightarrow D$
R2 = {BC} with $B \rightarrow C$
R3 = {BD} for the key

c. $AB \rightarrow D$ is implied by $B \rightarrow C$ and $AC \rightarrow D$ by law 4.

FD Basis: $B \rightarrow C$; $AC \rightarrow D$; $BD \rightarrow A$

Keys: AB, BD

Decomposition:
R1 = {BC} $B \rightarrow C$
R2 = {ACD} $AC \rightarrow D$
R3= {ABD} $BD \rightarrow A$

d. FD Basis: $D \rightarrow C$, $D \rightarrow E$, $BC \rightarrow A$, $BC \rightarrow D$

Keys: BC, BD

Decomposition step 1:
R1 = {CD} $D \rightarrow C$
R2 = {DE} $D \rightarrow E$
R3 = {ABC} $BC \rightarrow A$
R4= {BCD} $BC \rightarrow D$

Decomposition step 2:
R5 = R1 $\cup$ R2 = {CDE} $D \rightarrow C$, $D \rightarrow E$
R6 = R3 $\cup$ R4 = {ABCD} $BC \rightarrow A$, $BC \rightarrow D$

e.
(i) Find a minimal basis
Note that $C \rightarrow D$ and $D \rightarrow B$ imply $C \rightarrow B$. Then $C \rightarrow B$ implies $AC \rightarrow B$.
Thus, we can get rid of $AC \rightarrow B$.

Note that $BCD \rightarrow A$ is the same as $CD \rightarrow A$ because $D \rightarrow B$.
Then note that $CD \rightarrow A$ is the same as $C \rightarrow A$ because $C \rightarrow D$.
Thus we can replace $BCD \rightarrow A$ by $C \rightarrow A$.

Finally, the minimal basis is $B \rightarrow F$, $C \rightarrow A$, $C \rightarrow D$, $D \rightarrow B$, $EF \rightarrow C$.

(ii) Find the keys
Each key must contain E.
Consider:
$\{E\}^+ = \{E\}$
$\{EA\}^+ = \{EA\}$
$\{EB\}^+=\{ABCDEF\}$ key
$\{EC\}^+=\{ABCDEF\}$ key
$\{ED\}^+=\{ABCDEF\}$ key
$\{EF\}^+=\{ABCDEF\}$ key

Any superset of {EA} will be a superkey. Thus, all keys are {EB}, {EC}, {ED}, {EF}.

(iii) Decomposition

The corresponding decomposition is:
$R_1 = \{BF\}$, FD's: $B \rightarrow F$
$R_2 = \{AC\}$, FD's: $C \rightarrow A$
$R_3 = \{CD\}$, FD's: $C \rightarrow D$
$R_4 = \{BD\}$, FD's: $D \rightarrow B$
$R_5 = \{CEF\}$, FD's: $EF \rightarrow C$
$R_6 = \{BE\}$
$R_7 = \{DE\}$

Furthermore, we can combine R_2 and R_3 into $R_8 = \{ACD\}$ with $C \rightarrow A$ and $C \rightarrow D$.