COMP 3005: Database Management Systems (Due: Friday November 19, 2021 (11:59 PM))

Assignment #4

Instructor: Ahmed El-Roby *Name:* Ryan Lo, *ID:* 101117765

Instructions: Read all the instructions below carefully before you start working on the assignment, and before you make a submission.

- The accepted format for your submission is pdf only.
- If you use the tex file, make sure you edit line 28 to add your name and ID. Only write your solution and do not change anything else in the tex file. If you do, you will be penalized.
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- Late submissions are allowed for 24 hours after the deadline above with a penalty of 10% of the total grade of the assignment. Submissions after more than 24 are not allowed.

Q 1: (3 points)

In class, we showed that functional dependencies are transitive. That is, if $X \rightarrow Y$ and $Y \rightarrow Z$, then $X \rightarrow Z$. Assume a new proposed rule: If $X \rightarrow Y$ and $Z \rightarrow Y$, then $X \rightarrow Z$. Prove that this rule is incorrect.

Functional dependency $X \rightarrow Y$ means that every X is mapped to a unique value in Y.

For example :

You have a table

X	Y	Z
x1	y1	z1
x1	y1	z2
x2	y2	z3
x3	y3	z4

We can see that $X \rightarrow Y$ is true and $Z \rightarrow Y$ is true, but when we look at $X \rightarrow Z$, we can see that this is false.

Q 2: (3 points)

How can you use functional dependencies to represent the constraint that a relationship between two entity sets X and Y is one-to-many from X to Y.

If you have the functional dependency $Y \rightarrow X$ this makes X and Y a one-to-many from X to Y.

For example :

You have a table

X	Y
x1	y1
x1	y1
x2	y2
x2	y2
x2	y3

We can see that Y uniquely maps to a value in X but the relationship in X to Y can have one to many from X to Y.

Q 3: (8 points)

Consider the following relation $R = \{A, B, C, D, E\}$ and the following set of functional dependencies

$F = \{$

$A \rightarrow BC$

$CD \rightarrow E$

$B \rightarrow D$

$E \to A\}$
Compute B^+. Is R in BCNF? If not, give a lossless decomposition of R into BCNF. Show your work for all previous questions.

The trivial functional dependency, B is in B^+. In the function dependency F, we have $B \to D$, so D is in B^+. That gets us $B^+ = \{B, D\}$.

$A^+ = \{A, B, C, D, E\}$
$B^+ = \{B, D\}$
$C^+ = \{C\}$
$D^+ = \{D\}$
$E^+ = \{A, B, C, D, E\}$
$(BC)^+ = \{ABCDE\}$
$(CD)^+ = \{ABCDE\}$

The candidate keys are A, BC, CD, E because their closure is equal to R.

A relation is in BCNF if all functional dependencies F $\alpha \to \beta$ where α is a superkey. From our set of functional dependencies we can see that A, CD, E are all superkeys but B is not a super key. Therefore because of the functional dependency $B \to D$, this relation is not in BCNF.

If $\alpha \to \beta$ is the functional dependency that causes the violation of BCNF conditions then we want to decompose R into: $(\alpha \cup \beta)$ and $(R - (\beta - \alpha))$.

We have $B \to D$ as the functional dependency that causes the violation of BCNF for R.
Let R1 = $(\alpha \cup \beta)$ and R2 = $(R - (\beta - \alpha))$
R2 = $(R - (D - B)) = (R - D) = (ABCDE - D) = (ABCE)$
We take $R = \{A, B, C, D, E\}$ and decompose it to:
R1 = $\{BD\}$ and R2 = $\{ABCE\}$
This is a lossless decomposition because $R_1 \cap R_2 \to R_1$, so B is in R_1 and is common in R_1 and R_2.

Q 4: (4 points)

Give a lossless, dependency-preserving decomposition into 3NF of schema R in Q3.

$R = \{A, B, C, D, E\}$
$F = \{$
$A \to BC$
$CD \to E$
$B \to D$
$E \to A\}$

No extraneous attributes in F.
$F_c = \{A \to BC, CD \to E, B \to D, E \to A\}$
$R_1 = \{A, B, C\}$, $R_2 = \{C, D, E\}$, $R_3 = \{B, D\}$, $R_4 = \{E, A\}$

Q 5: (4 points)

Assume the following decomposition of R in Q3: $R_1(A, B, E)$ and $R_2(C, D, E)$. Is this decomposition lossy or lossless? Why? Show your work in detail.

$R = \{A, B, C, D, E\}$
$F = \{$
$A \to BC$
$CD \to E$
$B \to D$
$E \to A\}$

To figure out whether a decomposition is lossy or lossless.
If $R_1 \cap R_2 \to R_1$ or $R_1 \cap R_2 \to R_2$
$R_1 \cap R_2 \to R_1 = \{E\}$
Does $E \to ABE$ or $E \to CDE$?
$E \to E$, trivial, $E \to A$, and $A \to BC$
So, $E \to ABE$.
Another way is if $\pi_{R_1}(R) \bowtie \pi_{R_2}(R) = R$ if it is lossless.
$R \subset \pi_{R_1}(R) \bowtie \pi_{R_2}(R)$ if it is lossy.

$\pi_{R_1}(R) \bowtie \pi_{R_2}(R) = \{A, B, C, D, E\} = R$
Therefore it is a lossless decomposition.

Q 6: (22 points)

Consider the following relation $R(A, B, C, D, E, G)$ and the set of functional dependencies
$F = \{$
$A \to BCD$
$BC \to DE$
$B \to D$
$D \to A\}$

Note: Show the steps for each answer.

(a) Compute B^+. (4 points)

The the trivial FD of B gives us,
$B^+ = \{B\}$
$B^+ = \{B, D\}$ from $B \to D$
$B^+ = \{A, B, D\}$ from $D \to A$
$B^+ = \{A, B, C, D\}$ from $A \to BCD$
$B^+ = \{A, B, C, D, E\}$ from $BC \to DE$

(b) Prove (using Armstrong's axioms) that AG is superkey. (4 points)

By augmenting $A \to BCD$ with G we get $AG \to BCDG$,
By applying the decomposition rule to $AG \to BCDG$ we get $AG \to BC$, and by the transitive rule with $BC \to DE$ we get $AG \to DE$.
By applying the decomposition again to $AG \to BCDG$ we get $AG \to D$, and with the transitive rule to $D \to A$ we get $AG \to A$.
And with all of that we get $AG \to ABCDEG$. And since it equals to the relation R, AG is a superkey.

(c) Compute F_c. (6 points)

$R(A, B, C, D, E, G)$
$F = \{$
$A \to BCD$
$BC \to DE$
$B \to D$
$D \to A\}$

D is extraneous in $A \to BCD$
$F_c = \{A \to BC, BC \to DE, B \to D, D \to A\}$
D is extraneous in $BC \to DE$
$F_c' = \{A \to BC, BC \to E, B \to D, D \to A\}$
$(BC)^+ = \{A, B, C, D, E\}$ which includes D
$F_c = \{A \to BC, BC \to E, B \to D, D \to A\}$
C is extraneous in $BC \to E$
$F_c = \{A \to BC, B \to E, B \to D, D \to A\}$

(d) Give a 3NF decomposition of the given schema based on a canonical cover. (4 points)
$F_c = \{A \to BC, B \to E, B \to D, D \to A\}$
No deletion needed cause non of the schemas are subsets of another schema.
$R_1 = \{A, B, C\}$, $R_2 = \{B, E\}$, $R_3 = \{B, D\}$, $R_4 = \{A, D\}$

(e) Give a BCNF decomposition of the given schema based on F. Use the first functional dependency as the violator of the BCNF condition. (4 points)

$R(A, B, C, D, E, G)$
$F = \{$
$A \to BCD$
$BC \to DE$
$B \to D$
$D \to A\}$

In $A \to BCD$, A is not a superkey
We will decomposite this into $R_1 = \{A, B, C, D\}$ which is $\alpha \cup \beta$
and $R_2 = \{A, E, G\}$ which is $R - \beta$
In $BC \to DE$, BC is not a superkey
We will decomposite this into $R_3 = \{B, C, D, E\}$ which is $\alpha \cup \beta$
and $R_4 = \{A, B, C, G\}$ which is $R - \beta$
In $B \to D$, B is not a superkey
We will decomposite this into $R_5 = \{B, D\}$ which is $\alpha \cup \beta$
and $R_6 = \{A, B, C, E, G\}$ which is $R - \beta$
In $D \to A$, D is not a superkey
We will decomposite this into $R_7 = \{D, A\}$ which is $\alpha \cup \beta$
and $R_8 = \{B, C, D, E, G\}$ which is $R - \beta$
The final relation in BCNF is $R_1 = \{A, B, C, D\}$, $R_2 = \{A, E, G\}$, $R_3 = \{B, C, D, E\}$, $R_4 = \{A, B, C, G\}$, $R_5 = \{B, D\}$, $R_6 = \{A, B, C, E, G\}$, $R_7 = \{A, D\}$, $R_8 = \{B, C, D, E, G\}$

Q 7: (6 points)

Given the following set of functional dependencies:
$A \to BC$
$B \to AC$
$C \to AB$
Show that it is possible to find more than one unique canonical cover for this set.

First cannonical cover:
$F = \{A \to BC, B \to AC, C \to AB\}$
C is extraneous in $A \to BC$, on transitivity on $A \to B, B \to AC$
$F_c = \{A \to B, B \to AC, C \to AB\}$
A is extraneous in $B \to AC$
$F_c = \{A \to B, B \to C, C \to AB\}$
B is extraneous in $C \to AB$
$F_c = \{A \to B, B \to C, C \to A\}$

Second cannonical cover:
$F = \{A \to BC, B \to AC, C \to AB\}$
B is extraneous in $A \to BC$
$F_c = \{A \to C, B \to AC, C \to AB\}$
C is extraneous in $B \to AC$
$F_c = \{A \to C, B \to A, C \to AB\}$
B is extraneous in $C \to AB$
$F_c = \{A \to C, B \to A, C \to A\}$

Q 8 (7 points)

Consider the schema $R = (A, B, C, D, E, G)$ and the set F of functional dependencies:
$A \to BC$
$BD \to E$
$CD \to AB$
Use the BCNF decomposition algorithm to find a BCNF decomposition of R. Start with $A \to BC$. Explain your steps. Is this decomposition lossy or lossless? Is it dependency-preserving?

In $A \to BC$, A is not a superkey
We will decomposite this into $R_1 = \{A, B, C\}$ which is $\alpha \cup \beta$
and $R_2 = \{A, D, E, G\}$ which is $R - \beta$
Next, $BD \to E$, BD is not a superkey for R_2

We will decomposite this into $R_3 = \{B, D, E\}$ which is $\alpha \cup \beta$
and $R_4 = \{A, D, G\}$ which is $R_2 - \beta$
Lastly, $CD \to AB$, CD is not a superkey
We will decomposite this into $R_5 = \{A, B, C, D\}$ which is $\alpha \cup \beta$
and $R_6 = \{D, G\}$ which is $R_4 - \beta$
So, the relations are $\{A, B, C\}$, $\{B, D, E\}$, $\{A, B, C, D\}$, and $\{D, G\}$
It is dependency preserving and it is lossless.

Q 9: (3 points)

As discussed in class, SQL does not support functional dependency constraints. But it supports materialized views. Assume that the DBMS maintains the materialized view immediately. Given a relation $R(W, X, Y, Z)$, how would you use materialized views to enforce the functional dependency $W \to Z$?

The materialized view would be such that W must only have one relation of Z. Using the unique keyword in the materialized view between the two relations W and Z, should create a functional dependency between them.