CZ2007 Tutorial 3:
FDs + BCNF

Week 5

Question 1

- A medical clinic database schema contains the following:
- APPOINTMENT (patient-id, patient-name, doctor-id, doctor-name, appointment-date, appointment-time, clinic-room-no)
- Show, with suitable examples, the anomalies that the schema is liable to encounter.
- Key is patient-id.
- So FD is patient-id $\rightarrow$ patient-name, doctor-id, doctor-name, appointment-date, appointment-time, clinic-room-no

Question 1

APPOINTMENT (patient-id, patient-name, doctor-id, doctor-name, appointment-date, appointment-time, clinic-room-no)

patient-id	patient-name	doctor-id	doctor-name	appt-date	appt-time	room-no
p001	john	d100	james	20.01.01	0930	r01
p002	steve	d100	james	20.01.02	1030	r09
p003	william	d100	james	20.01.03	0930	r08
p004	charles	d100	james	20.01.04	1030	r07

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p003	william	d100	james	20.01.03	0930	r08
p004	charles	d100	james	20.01.04	1030	r07
2 p005	bob	null	null	null	null	null

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p004	charles	d100	james	20.01.04	1030	r07
2 p005	bob	null	null	null	null	null
null	null	3 d102	lee	null	null	null

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Question 1

APPOINTMENT (<u>patient-id</u>, patient-name, doctor-id, doctor-name, appointment-date, appointment-time, clinic-room-no)

patient-id	patient-name	doctor-id	doctor-name	appt-date	appt-time	room-no
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p002	steve	d100	1 james	20.01.02	1030	r09
p003	william	d100	james	20.01.03	0930	r08
p004	charles	d100	james	20.01.04	1030	r07
2 p005	bob	null	null	null	null	null
null	null	3 d102	lee	null	null	null
4 p003	william	d100	james	20.01.10	1030	r10
p003	william	d110	michael	20.01.11	1130	r10

Question 1

Clearly doctor-id $\rightarrow$ doctor-name is an FD and LHS is not superkey

1 We must ensure that the doctor attributes are consistent with other patients under this doctor; potential update anomalies

2 In order to insert a new patient, all the attributes of the doctor who is treating the patient must be also included; if no doctor, then use NULL, which is not good.

3 If a new doctor joins and has not seen any patients, we cannot enter the doctor's details. We cannot fill patient information with NULLs since this violates the primary key condition.

4 If the same patient has more than one appointment, its ID will be repeated, which violates the unique property of a key.

Question 1

- APPOINTMENT (<u>patient-id</u>, patient-name, doctor-id, doctor-name, appointment-date, appointment-time, clinic-room-no)
- **Can we infer all FDs in this relation?**
- patient-id → patient-name
- doctor-id → doctor-name
- patient-id, doctor-id → appointment-date, appointment-time, clinic-room-no ?
- appointment-date, appointment-time, clinic-room-no → patient-id, doctor-id ?

Question 2

- Consider the relation ADDRESS having attributes Street, City, State and Zip.
- Assume that for any given zipcode, there is just one city and state. Also, for any given street, city, and state, there is just one zipcode.
- (a) Infer all possible functional dependencies (FDs) for this relation.
- (b) Which are possible minimal keys?

Question 2

- Let us denote attributes STREET, CITY, STATE, ZIP as A, B, C and D respectively. Then we have D $\rightarrow$ BC and ABC $\rightarrow$ D.

- Use closure to find FDs:
  - $A^+=\{A\}$; $B^+=\{B\}$; $C^+=\{C\}$; $D^+=\{DBC\}$
  - $AB^+=\{AB\}$; $AC^+=\{AC\}$; $AD^+=\{\underline{ABCD}\}$; $BC^+=\{BC\}$; $BD^+=\{BDC\}$; $CD^+=\{CDB\}$;
  - $ABC^+=\{\underline{ABCD}\}$; $ABD^+=\{ABCD\}$; $ACD^+=\{ABCD\}$; $BCD^+=\{BCD\}$

Question 2

- FD's:
  - $D \rightarrow BC$ because $D+=\{DBC\}$
  - $AD \rightarrow BC$ because $AD^{+}=\{\underline{ABCD}\}$
  - $BD \rightarrow C$ because $BD^{+}=\{BDC\}$
  - $CD \rightarrow B$ because $CD^{+}=\{CDB\}$
  - $ABC \rightarrow D$ because $ABC^{+}=\{\underline{ABCD}\}$
  - $ABD \rightarrow C$ because $ABD^{+}=\{ABCD\}$
  - $ACD \rightarrow B$ because $ACD^{+}=\{ABCD\}$
- Minimal keys: ABC, AD

Question 3

- Prove the following properties using Armstrong's axioms or reject it by counterexample relations.
- (a) $A \rightarrow B \Rightarrow AC \rightarrow B$
- (b) $A \rightarrow C$ and $AB \rightarrow C \Rightarrow B \rightarrow C$

Question 3a

- (a) $A \rightarrow B \Rightarrow AC \rightarrow B$
- $A \rightarrow B \Rightarrow AC \rightarrow BC$ (Augmentation Rule)
- $BC \rightarrow B$ (Reflexivity Rule)
- $AC \rightarrow BC$ and $BC \rightarrow B \Rightarrow AC \rightarrow B$ (Transitivity Rule)

Question 3b

- (b) $A \longrightarrow C$ and $AB \longrightarrow C \Rightarrow B \longrightarrow C$
- Consider the records:
- (a1, b1, c1)
- (a2, b1, c2)
- Both $A \rightarrow C$ and $AB \rightarrow C$ are true but $B \rightarrow C$ does not hold

Question 4

4. Consider a relation R(A, B, C, D) with the following FDs: $B \rightarrow C$, $D \rightarrow B$

   (a) Find the key(s) of R.
   (b) Is this relation in BCNF? Why or why not? If it is not, decompose R

   into a collection of relations that are in BCNF.

Question 4

- Use closure to find FDs:
  - $A^+=\{A\}$; $B^+=\{BC\}$; $C^+=\{C\}$; $D^+=\{DBC\}$
  - $AB^+=\{ABC\}$; $AC^+=\{AC\}$; $AD^+=\{\underline{ABCD}\}$; $BC^+=\{BC\}$; $BD^+=\{BCD\}$; $CD^+=\{BCD\}$;
  - $ABC^+=\{ABC\}$; $ABD^+=\{\underline{ABCD}\}$; $ACD^+=\{\underline{ABCD}\}$; $BCD^+=\{BCD\}$
  - Key is AD
- Also we note that A and D do not appear on RHS of FDs; so key must contain AD. In fact, key is AD.

Question 4

- Key is AD.
- Both FDs $B \rightarrow C$, $D \rightarrow B$ violate BCNF. Can decompose using either one first.
- By first decomposing on $B \rightarrow C$, we get R1(B, C) and R2(A, B, D).
- R2 is not in BCNF due to violating FD $D \rightarrow B$, so we decompose further: R3(A,D) and R4(B, D).
- Both R3 and R4 are in BCNF (see Q5)

Question 4

- By first decomposing on D $\rightarrow$ B, we get R1(B, C, D) and R2(A, D).
- R1 is not in BCNF due to violating FD B $\rightarrow$ C, so we must decompose further.
- In both cases, we end up with three relations, Ra(A, D), Rb(B, C) and Rc(B, D).

Question 5

- Prove that every two-attribute relationis in BCNF.

- There are 4 cases in a two-attribute relation.

Question 5

- Case 1: $A \rightarrow B$ holds, but $B \rightarrow A$ does not. A is the key. The only nontrivial FD is $A \rightarrow B$; no BCNF violation.

- Case 2: $B \rightarrow A$ holds, but $A \rightarrow B$ does not. B is the key. The only nontrivial FD is $B \rightarrow A$; no BCNF violation.

- Case 3: Both $A \rightarrow B$ and $B \rightarrow A$ hold. A and B are both keys; no BCNF violation.

- Case 4: AB is key; so we have $AB \rightarrow AB$, which trivial.


Do the best
you can until you know better.
Then when you know better, do better.
~ Maya Angelou
ALL THE BEST