CS2102 Week 13 Tutorial

9 Nov 2021

Quick Recap

Dependency Preservation

When a relation is decomposed into multiple relations, at least one relation must satisfy each and every functional dependency present in the original relation.

Dependency Preservation

When a relation is decomposed into multiple relations, at least one relation must satisfy each and every functional dependency present in the original relation.

1. Check the closures on each decomposed relation.
2. Union these closures
3. Derive any implicit FDs using Armstrong Axioms
4. Check if any FDs are missing from the original set of FDs.

Dependency Preservation (Prime Attribute)

Prime attributes are attributes that appear in some key in relation R.

Normalization (3NF)

Why?

It is always possible to find a lossless-join dependency preserving decomposition via 3NF synthesis.

Normalization (3NF)

A relation R is in 3NF if every FD is either:

1. Trivial
2. Left hand side is a superkey
3. <u>Right hand side is a prime attribute</u>

Normalization (Minimal Basis / Minimal Cover)

Let us assume we have relation R and set of FDs F

To determine a minimal basis = F_b

1. Every FD in F_b can be derived from F and vice versa
2. Every FD in F_b is not trivial and decomposed
3. For each FD in F_b none of attributes in LHS is redundant
4. No FD in F_b is redundant

Normalization (Minimal Basis / Minimal Cover)

Algorithm:

1. Transform F such that it only contains non-trivial and decomposed FDs
2. Remove redundant attributes on the LHS of each FD
3. Remove redundant FDs

Normalization (Minimal Basis / Minimal Cover)

Algorithm:

1. Transform F such that it only contains non-trivial and decomposed FDs
2. Remove redundant attributes on the LHS of each FD
   a. Let us assume R(A, B, C, D, E) and F = { AB -> CDE, B -> CDE }
   b. AB^+ = ABCDE and B^+ = BCDE. Therefore A is a redundant attribute
3. Remove redundant FDs

Normalization (Minimal Basis / Minimal Cover)

Algorithm:

1. Transform F such that it only contains non-trivial and decomposed FDs
2. Remove redundant attributes on the LHS of each FD
3. Remove redundant FDs
   a. Let us assume R(A, B, C) and F = { A -> B, B -> C, A -> C }
   b. Check by removing A -> B and F^- = { B -> C, A -> C }
   c. A^+ wrt F^- = AC and A^+ wrt F = ABC
   d. Therefore, A -> B is <u>not</u> redundant

Normalization (Minimal Basis / Minimal Cover)

Algorithm:

1. Transform F such that it only contains non-trivial and decomposed FDs
2. Remove redundant attributes on the LHS of each FD
3. Remove redundant FDs
   a. Let us assume R(A, B, C) and F = { A -> B, B -> C, A -> C }
   b. Check by removing A -> C and F^- = { A -> B, B -> C }
   c. A^+ wrt F^- = ABC and A^+ wrt F = ABC
   d. Therefore, A -> C is redundant

Normalization (3NF Synthesis)

Algorithm:

1. Derived minimal basis of F, aka F_b
2. Combine the FDs via union rule
3. Create a table for each FD in the minimal basis F_b
4. If none of the tables contain a key of R, pick a key and create a table based on its attributes

Tutorial Questions

Question 1

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

Question 1(a)

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

(a) Schema $R(A, B, C, D)$ with $F = \{A \to BCD, C \to D\}$ and decomposition $\{R1(A, B, C), R2(C, D)\}$

Question 1(a)

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

(a) Schema $R(A, B, C, D)$ with $F = \{A \rightarrow BCD, C \rightarrow D\}$ and decomposition $\{R1(A, B, C), R2(C, D)\}$

Check $R_1(A, B, C)$:

1. $\{A\}+ = \{A, B, C\}$, $\{B\}+ = \{B\}$, $\{C\}+ = \{C\}$
2. Therefore, $F_1 = \{A \rightarrow B, A \rightarrow C\}$

Check $R_2(C, D)$

1. $\{C\}+ = \{C, D\}$, $\{D\}+ = \{D\}$
2. Therefore, $F_2 = \{C \rightarrow D\}$

Question 1(a)

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

(a) Schema $R(A, B, C, D)$ with $F = \{A \to BCD, C \to D\}$ and decomposition $\{R1(A, B, C), R2(C, D)\}$

Check $F' = F_1 \cup F_2 = \{A \to B, A \to C, C \to D\}$

1. $F' \vDash C \to D$ (Transitivity $A \to C$ and $C \to D$)
2. $F' = \{A \to B, A \to C, A \to D, C \to D\}$
3. $F' \equiv \{A \to BCD, C \to D\} = F$

Therefore, this is a dependency-preserving decomposition

Question 1(b)

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

(b) Schema $R(A, B, C, D)$ with $F = \{A \rightarrow BCD, C \rightarrow D\}$ and decomposition $\{R1(A, C), R2(A, B, D)\}$

Question 1(b)

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

(b) Schema $R(A, B, C, D)$ with $F = \{A \rightarrow BCD, C \rightarrow D\}$ and decomposition $\{R1(A, C), R2(A, B, D)\}$

Check $R_1(A, C)$:

1. $\{A\}+ = \{A, C\}$ and $\{C\}+ = \{C\}$
2. Therefore, $F_1 = \{A \rightarrow C\}$

Check $R_2(A, B, D)$:

1. $\{A\}+ = \{A, B, D\}$, $\{B\}+ = \{B\}$, $\{D\}+ = \{D\}$
2. Therefore, $F_2 = \{A \rightarrow B, A \rightarrow D\}$

Question 1(b)

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

(b) Schema $R(A, B, C, D)$ with $F = \{A \to BCD, C \to D\}$ and decomposition $\{R1(A, C), R2(A, B, D)\}$

Check $F' = F_1 \cup F_2 = \{A \to B, A \to C, A \to D\}$

1. $F' = \{A \to B, A \to C, A \to D\}$
2. $F' \not\equiv \{A \to BCD, C \to D\} = F$
3. This is because $C \to D$ is not preserved.

Therefore, this is **NOT** a dependency-preserving decomposition

Question 1(b)

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

(c) Schema $R(A, B, C, D, E)$ with $F = \{AB \rightarrow C, AC \rightarrow D, E \rightarrow ABCD\}$ and decomposition $\{R1(A, B, C), R2(A, B, E), R3(A, C, D)\}$

Question 1(b)

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

(c) Schema $R(A, B, C, D, E)$ with $F = \{AB \rightarrow C, AC \rightarrow D, E \rightarrow ABCD\}$ and decomposition $\{R1(A, B, C), R2(A, B, E), R3(A, C, D)\}$

Check $R_1(A, B, C)$:

1. $\{A, B\}+ = \{A, B, C\}$
2. Therefore, $F_1 = \{AB \rightarrow C\}$

Check $R_2(A, B, E)$:

1. $\{E\}+ = \{A, B, E\}$
2. Therefore, $F_2 = \{E \rightarrow A, E \rightarrow B\}$

Check $R_3(A, C, D)$:

1. $\{A, C\}+ = \{A, C, D\}$
2. Therefore, $F_2 = \{AC \rightarrow D\}$

Question 1(b)

1. For each of the following schema decomposition, determine whether or not it is a dependency-preserving decomposition.

(c) Schema $R(A, B, C, D, E)$ with $F = \{AB \rightarrow C, AC \rightarrow D, E \rightarrow ABCD\}$ and decomposition $\{R1(A, B, C), R2(A, B, E), R3(A, C, D)\}$

Check $F' = F_1 \cup F_2 \cup F_3 = \{AB \rightarrow C, AC \rightarrow D, E \rightarrow A, E \rightarrow B\}$

1. $F' \vDash E \rightarrow C$ (Transitivity $E \rightarrow AB$ and $AB \rightarrow C$)
2. $F' = \{AB \rightarrow C, AC \rightarrow D, E \rightarrow A, E \rightarrow B, E \rightarrow C\}$
3. $F' \vDash E \rightarrow D$ (Transitivity $E \rightarrow AC$ and $AC \rightarrow D$)
4. $F' = \{AB \rightarrow C, AC \rightarrow D, E \rightarrow A, E \rightarrow B, E \rightarrow C, E \rightarrow D\}$
5. $F' \equiv \{AB \rightarrow C, AC \rightarrow D, E \rightarrow ABCD\} = F$

Therefore, this is a dependency-preserving decomposition

Question 1

Learning Objectives:

1. Understand how to determine if a decomposition is dependency-preserving or not
2. Apply the usage of armstrong axioms to determine implicit FDs which are not obvious

Question 2

2. Consider the schema $R(A, B, C, D)$ with $F = \{ABC \rightarrow D, D \rightarrow A\}$.

Question 2(a)

2. Consider the schema $R(A, B, C, D)$ with $F = \{ABC \rightarrow D, D \rightarrow A\}$.

(a) Is R in BCNF? Explain.

Question 2(a)

2. Consider the schema $R(A, B, C, D)$ with $F = \{ABC \to D, D \to A\}$.

(a) Is R in BCNF? Explain.

Check $ABC \to D$:

1. $ABC \to D$ is not trivial
2. $\{A, B, C\}+ = \{A, B, C, D\}$

Check $D \to A$:

1. $D \to A$ is not trivial
2. $\{D\}+ = \{A, D\}$ and that D is not a superkey

Therefore, R is not in BCNF

Question 2(b)

2. Consider the schema $R(A, B, C, D)$ with $F = \{ABC \rightarrow D, D \rightarrow A\}$.

(b) Is R in 3NF? Explain.

Question 2(b)

2. Consider the schema $R(A, B, C, D)$ with $F = \{ABC \to D, D \to A\}$.

(b) Is R in 3NF? Explain.

Check $ABC \to D$:

1. $ABC \to D$ is not trivial
2. $\{A, B, C\}+ = \{A, B, C, D\}$

Check $D \to A$:

1. $D \to A$ is not trivial
2. $\{D\}+ = \{A, D\}$ and that D is not a superkey
3. A is a prime attribute as ABC is a key of R

Therefore, R is in 3NF

Question 2

Learning Objectives:

1. Learn how to determine if a schema or a set of decomposed schema is in BCNF or 3NF or neither.

Question 3

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \to E, CD \to A, E \to B, E \to D, A \to BD\}$.

Question 3

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \to E, CD \to A, E \to B, E \to D, A \to BD\}$.

1. $\{A\}+ = \{A, B, D, E\}$
2. $\{C, D\}+ = \{A, B, C, D, E\}$
3. $\{E\}+ = \{B, D, E\}$
4. $\{A, C\}+ = \{A, B, C, D, E\}$
5. $\{C, E\}+ = \{A, B, C, D, E\}$

Question 3(a)

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \to E, CD \to A, E \to B, E \to D, A \to BD\}$.

(a) Is R in 3NF? Explain.

Question 3(a)

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \to E, CD \to A, E \to B, E \to D, A \to BD\}$.

(a) Is R in 3NF? Explain.

Check $A \to E$

1. $A \to E$ is not trivial
2. $\{A\}+ = \{A, B, D, E\}$
3. E is a prime attribute of key CE

Check $CD \to A$

1. $CD \to A$ is not trivial
2. $\{C, D\}+ = \{A, B, C, D, E\}$

Check $E \to B$

1. $E \to B$ is not trivial
2. $\{E\}+ = \{B, D, E\}$
3. B is not a prime attribute of any key.

Therefore, R is not in BCNF

Erreta:
Therefore, R is NOT in 3NF, not BCNF

Question 3(b)

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A \rightarrow BD\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

Question 3(b)

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A \rightarrow BD\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

Let $F' = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A, \rightarrow D, A \rightarrow B\}$

Attribute Redundancy:

1. None of the attributes are redundant
   (a) Given $CD \rightarrow A$: $\{C, D\}+ = \{A, B, C, D, E\}$
   (b) By removing C, $\{D\}+ = \{D\} \neq \{A, B, D, E\}$
   (c) By removing D, $\{C\}+ = \{C\} \neq \{A, B, C, E\}$

Question 3(b)

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A \rightarrow BD\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

Let $F' = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A \rightarrow B, A \rightarrow D\}$

FD Redundancy:

1. $A \rightarrow B$ is redundant
   (a) Let $F' = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A \rightarrow D\}$
   (b) $A+$ wrt $F' = ABDE$
   (c) $A+$ wrt $F = ABDE$
   (d) Therefore, we can conclude $A \rightarrow B$ is redundant

Question 3(b)

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \to E, CD \to A, E \to B, E \to D, A \to BD\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

Remove $A \to B$ from F':
Let $F' = \{A \to E, CD \to A, E \to B, E \to D, A \to D\}$

FD Redundancy:

1. $A \to D$ is redundant
   (a) Let $F' = \{A \to E, CD \to A, E \to B, E \to D\}$
   (b) $A+$ wrt $F' = ABDE$
   (c) $A+$ wrt $F = ABDE$
   (d) Therefore, we can conclude $A \to D$ is also redundant

Question 3(b)

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A \rightarrow BD\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

1. $F_b = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D\}$
2. From this, $F_b = \{A \rightarrow E, CD \rightarrow A, E \rightarrow BD\}$
3. Construct $R_1(A, E)$, $R_2(A, C, D)$, $R_3(B, D, E)$
4. Keys AC and CD are contained within R_2 and R_3 respectively
5. Therefore, no need to construct an additional table

Erreta:
AC and CD are contained within R2 only.

Question 3

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A \rightarrow BD\}$.

(c) Is your decomposition in (b) in BCNF?

Question 3

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A \rightarrow BD\}$.

(c) Is your decomposition in (b) in BCNF?

- R_1 is in BCNF as it has only 2 attributes
- R_2 is not in BCNF
  - $F_2 = \{A \rightarrow D\}$ and that $A+ = AD$
  - $A \rightarrow D$ is not trivial and A is not a key of F_2

Hence, this decomposition is **NOT** in BCNF

Erreta:
R2 also contains the FD of
CD -> A, but the reasoning is the same

Question 3

3. Consider the schema $R(A, B, C, D)$ with $F = \{A \rightarrow E, CD \rightarrow A, E \rightarrow B, E \rightarrow D, A \rightarrow BD\}$.

(c) Is your decomposition in (b) in BCNF?

Note that not all 3NF synthesis will result in a decomposition that is in BCNF

It is possible to find one, but it might take too much time to do so.

Question 3

Learning Objectives:

1. Learn how to determine if a schema or a set of decomposed schema is in BCNF or 3NF or neither..
2. Use minimal basis and decomposition to execute 3NF synthesis to derive your new set of decomposed relations

Question 4

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \to CDE, AC \to BDE, B \to C, C \to B, C \to D, B \to E\}$.

Question 4

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \to CDE, AC \to BDE, B \to C, C \to B, C \to D, B \to E\}$.

- $\{A, B\}+ = \{A, B, C, D, E\}$
- $\{A, C\}+ = \{A, B, C, D, E\}$

Question 4(a)

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \rightarrow CDE, AC \rightarrow BDE, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$.

(a) Is R in 3NF? Explain.

Question 4(a)

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \to CDE, AC \to BDE, B \to C, C \to B, C \to D, B \to E\}$.

(a) Is R in 3NF? Explain.

Question 4(a)

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \rightarrow CDE, AC \rightarrow BDE, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$.

(a) Is R in 3NF? Explain.

Check $C \rightarrow D$

- $C \rightarrow D$ is not trivial
- $\{C\}+ = \{B, C, D, E\}$ and C is not a superkey
- D is not a prime attribute of either key AB or AC

Therefore, R is not in 3NF

Question 4(b)

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \to CDE, AC \to BDE, B \to C, C \to B, C \to D, B \to E\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

Question 4(b)

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \rightarrow CDE, AC \rightarrow BDE, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

Let $F' = \{AB \rightarrow CDE, AC \rightarrow BDE, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$

Attribute Redundancy:

1. A in $AB \rightarrow CDE$ is redundant
   (a) By removing A, $\{B\}+ = \{B, C, D, E\}$
2. A in $AC \rightarrow BDE$ is redundant
   (a) By removing A, $\{C\}+ = \{B, C, D, E\}$
3. Therefore, $F' = \{B \rightarrow CDE, C \rightarrow BDE, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$

Question 4(b)

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \rightarrow CDE, AC \rightarrow BDE, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

Given $F' = \{B \rightarrow CDE, C \rightarrow BDE, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$,
Remove duplicate FDs:
Let $F' = \{B \rightarrow D, C \rightarrow E, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$

FD Redundancy:

1. $B \rightarrow D$ is redundant
   (a) Let $F' = \{C \rightarrow E, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$
   (b) $B+$ wrt $F' = BCDE$
   (c) $B+$ wrt $F = BCDE$
   (d) Therefore, we can conclude $B \rightarrow D$ is also redundant

Question 4(b)

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \rightarrow CDE, AC \rightarrow BDE, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

Remove $B \rightarrow D$ from F':
Let $F' = \{C \rightarrow E, B \rightarrow C, C \rightarrow B, C \rightarrow D, B \rightarrow E\}$

FD Redundancy:

1. $B \rightarrow E$ is redundant
   (a) Let $F' = \{C \rightarrow E, B \rightarrow C, C \rightarrow B, C \rightarrow D\}$
   (b) $B+$ wrt $F' = BCDE$
   (c) $B+$ wrt $F = BCDE$
   (d) Therefore, we can conclude $B \rightarrow E$ is also redundant

Question 4(b)

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \to CDE, AC \to BDE, B \to C, C \to B, C \to D, B \to E\}$.

(b) If R is not in 3NF, find a 3NF decomposition of R.

1. $F_b = \{C \to E, B \to C, C \to B, C \to D\}$
2. From this, $F_b = \{B \to C, C \to BDE\}$
3. Construct $R_1(B,C)$, $R_2(B,C,D,E)$
4. Keys AB and AC are not contained at all.
5. Therefore, construct an additional table: $R_3(A,B)$
6. Thus, our decomposition is $R_1(B,C)$, $R_2(B,C,D,E)$, $R_3(A,B)$

Erreta:
R1 is not needed since R1 has a subset of attributes of R2 and hence, you just need R2 and R3 for your final answer.

Question 4

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \to CDE, AC \to BDE, B \to C, C \to B, C \to D, B \to E\}$.

(c) Is your decomposition in (b) in BCNF?

Question 4

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \to CDE, AC \to BDE, B \to C, C \to B, C \to D, B \to E\}$.

(c) Is your decomposition in (b) in BCNF?

Question 4

4. Consider the schema $R(A, B, C, D, E)$ with $F = \{AB \to CDE, AC \to BDE, B \to C, C \to B, C \to D, B \to E\}$.

(c) Is your decomposition in (b) in BCNF?

- R_1 is in BCNF as it has only 2 attributes
- R_2 is in BCNF as
  - $F_2 = \{B \to C, C \to B, C \to D, B \to E\}$
  - Also, $F_2 \vDash B \to D$ and $F_2 \vDash C \to E$
  - Hence, $\{B\}+ = \{B, C, D, E\}$ and $\{C\}+ = \{B, C, D, E\}$
  - All the FDs are non-trivial
  - but the LHS of each FD is a superkey, either B or C
  - hence, R_2 must be in BCNF
- R_3 is in BCNF as it has only 2 attributes

Hence, this decomposition is in BCNF

Erreta:
R1 is not needed since R1 has a subset of attributes of R2 and hence, you just need to explain R2 and R3

Question 4

Learning Objectives:

1. Learn how to determine if a schema or a set of decomposed schema is in BCNF or 3NF or neither..
2. Use minimal basis and decomposition to execute 3NF synthesis to derive your new set of decomposed relations

Thank You!