BT5110 Data Management and Warehousing

Tutorial 5: Normalisation
(Extra Practice)

Mark Meng Huasong

School of Computing
National University of Singapore

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- Extra Case No.1 - Warehouse management system
- Extra Case No.2 - University transcript issuing system
- Extra Case No.3 (Abstract) - *Non dependency preserving decomposition*
- Extra Case No.4 (Abstract) - *Candidate keys with different sizes*
- In-class Case No.1 (Abstract)
- In-class Case No.2 (Abstract) - *Trick wanted for finding candidate key(s)*

Boss Level Extra - Case 1

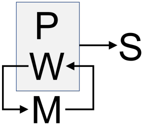
We are designing a warehouse management system for a lot of warehouses. Each warehouse (W) has one manager (M), and each manager only manage one warehouse. There could be many products (P) in per warehouse. For each product we also record its stock number (S).

Questions:
(1) Find **candidate key(s)** and **prime attribute(s)** from attribute closures Σ^+.
(2) Compute the **compact minimal cover** of R with all FDs Σ.
(3) Determine if it is **2NF**? If yes, is it **3NF**? If yes, is it **BCNF**?
(4) If it is not 3NF, **synthesis** the relations to make it 3NF.
(5) If it is not BCNF, **decomposite** the relations to make it BCNF and verify the **dependency preservation**.

Boss Level Extra - Case 1 (Solution)

W: warehouse; **M**: manager; **P**: product; **S**: stock.

$R = \{W, M, P, S\}$
$\Sigma = \{\{W\} \rightarrow \{M\}, \{M\} \rightarrow \{W\}, \{W, P\} \rightarrow \{S\}\}$.



Boss Level Extra - Case 1 (Solution)

$R = \{W, M, P, S\}$
$\Sigma = \{\{W\} \rightarrow \{M\}, \{M\} \rightarrow \{W\}, \{W, P\} \rightarrow \{S\}\}.$

Solution:
(1) The attribute closure of R is:

$$\begin{aligned}\Sigma^+ = \{&\{W\}^+ \rightarrow \{W, M\},\\ &\{M\}^+ \rightarrow \{W, M\},\\ &\{P\}^+ \rightarrow \{P\},\\ &\{S\}^+ \rightarrow \{S\},\\ &\{M, W\}^+ \rightarrow \{W, M\},\\ &\{M, P\}^+ \rightarrow \{W, M, P, S\},\\ &\{M, S\}^+ \rightarrow \{W, M, S\},\\ &\{W, P\}^+ \rightarrow \{W, M, P, S\},\\ &\{W, S\}^+ \rightarrow \{W, M, S\}, \ldots\}.\end{aligned}$$

Now we find candidate keys: $\{W, P\}$ and $\{M, P\}$.
Prime attributes: W, M, P

Boss Level Extra - Case 1 (Solution)

(2) The compact minimal cover is:

$\{W\} \rightarrow \{M\}$,
$\{M\} \rightarrow \{W\}$,
$\{W, P\} \rightarrow \{S\}$.

(3) Yes it is 2NF, 3NF, but not BCNF (e.g., $\{W\} \rightarrow \{M\}$, where $\{W\}$ is not a superkey).

(4) Omitted as it is 3NF.

(5) Decomposition at $\{W\} \rightarrow \{M\}$:

$R_1 = (\underline{W}, \underline{M})$,
$R_2 = (\underline{W}, \underline{P}, S)$.

It is (luckily) dependency preserving.

Boss Level Extra - Case 2

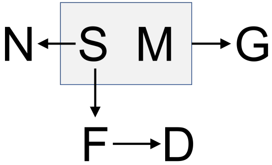
We are designing a transcript issuing system for our university. Each student is identified by its matric number/student ID, written as S. We are going to record a grade (G) for each student (S) and each module (M). We also record students' names (N) and their faculty (F). In case any verification is needed, we also save the dean's name for each department (D) so that people can contact him/her.

Questions:
(1) Find **candidate key(s)** and **prime attribute(s)** from attribute closures Σ^+.
(2) Compute the **compact minimal cover** of R with all FDs Σ.
(3) Determine if it is **2NF**? If yes, is it **3NF**? If yes, is it **BCNF**?
(4) If it is not 3NF, **synthesis** the relations to make it 3NF.
(5) If it is not BCNF, **decomposite** the relations to make it BCNF and verify the **dependency preservation**.

Boss Level Extra - Case 2 (Solution)

S: student ID; **M**: module; **N**: name; **F**: faculty; **G**: grade; **D**: dean

$R = \{S, M, G, N, F, D\}$
$\Sigma = \{\{S, M\} \rightarrow \{G\}, \{S\} \rightarrow \{N, F\}, \{F\} \rightarrow \{D\}\}.$



Boss Level Extra - Case 2 (Solution)

$R = \{S, M, G, N, F, D\}$
$\Sigma = \{\{S, M\} \rightarrow \{G\}, \{S\} \rightarrow \{N, F\}, \{F\} \rightarrow \{D\}\}$.

Solution:
(1) The attribute closure of R is:

$$\begin{aligned}\Sigma^+ = \{&\{S\}^+ \rightarrow \{S, N, F, D\},\\ &\{M\}^+ \rightarrow \{M\},\\ &\{G\}^+ \rightarrow \{G\},\\ &\{N\}^+ \rightarrow \{N\},\\ &\{F\}^+ \rightarrow \{F, D\},\\ &\{D\}^+ \rightarrow \{D\},\\ &\{S, M\}^+ \rightarrow \{S, M, N, F, D, G\},\\ &\{S, G\}^+ \rightarrow \{S, G, N, F, D\}, \ldots\end{aligned}$$

Now we find candidate keys: $\{S, M\}$.
Prime attributes: S, M

Boss Level Extra - Case 2 (Solution)

(2) The compact minimal cover is:

$\{S, M\} \rightarrow \{G\}$,
$\{S\} \rightarrow \{N, F\}$,
$\{F\} \rightarrow \{D\}$.

(3) No it is not 2NF (e.g., $\{S\} \rightarrow \{N, F\}$, {N, F} are not prime attributes and S is a subset of candidate key). Therefore it is not 3NF, and not BCNF, too.

(4) Synthesis result has 3 relations and is (luckily) BCNF:

$R_1 = (\underline{S}, \underline{M}, G)$,
$R_2 = (\underline{S}, N, F)$,
$R_3 = (\underline{F}, D)$.

Boss Level Extra - Case 2 (Solution)

(5) Decomposition at $\{F\} \rightarrow \{D\}$:

$R_1 = (\underline{F}, D)$,
$R_2 = (\underline{S}, \underline{M}, G, N, F)$.

However, R_2 needs to be further decomposed, at $\{S\} \rightarrow \{N\}$:

$R_{2.1} = (\underline{S}, N, F)$.
$R_{2.2} = (\underline{S}, \underline{M}, G)$.

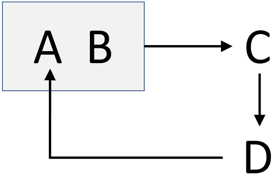
As the result, the BCNF decomposition is (luckily) dependency preserving and is given below:

$R_1 = (\underline{F}, D)$,
$R_{2.1} = (\underline{S}, N, F)$.
$R_{2.2} = (\underline{S}, \underline{M}, G)$.

(In fact this decomposition result is same with the synthesis one)

Boss Level Extra - Case 3

This time we deal with abstract relations with functional dependencies shown as in the figure below:



Questions:

(1) Find **candidate key(s)** and **prime attribute(s)** from attribute closures Σ^+.

(2) Compute the **compact minimal cover** of R with all FDs Σ.

(3) Determine if it is **2NF**? If yes, is it **3NF**? If yes, is it **BCNF**?

(4) If it is not 3NF, **synthesis** the relations to make it 3NF.

(5) If it is not BCNF, **decomposite** the relations to make it BCNF and verify the **dependency preservation**.

Boss Level Extra - Case 3 (Solution)

Solution:
(1) The attribute closure of $R = \{A, B, C, D\}$ is:

$$\begin{aligned}\Sigma^+ = \{&\{A\}^+ \rightarrow \{A\},\\ &\{B\}^+ \rightarrow \{B\},\\ &\{C\}^+ \rightarrow \{A, C, D\},\\ &\{D\}^+ \rightarrow \{A, D\},\\ &\{A, B\}^+ \rightarrow \{A, B, C, D\},\\ &\{A, C\}^+ \rightarrow \{A, C, D\},\\ &\{A, D\}^+ \rightarrow \{A, D\},\\ &\{B, C\}^+ \rightarrow \{A, B, C, D\}\\ &\{B, D\}^+ \rightarrow \{A, B, C, D\}, \ldots\end{aligned}$$

Now we find candidate keys: $\{A, B\}$ or $\{B, C\}$ or $\{B, D\}$.
Prime attributes: A, B, C, D (There is no non-prime attribute for this case)

Boss Level Extra - Case 3 (Solution)

(2) The compact minimal cover is:

$\{A, B\} \rightarrow \{C\}$
$\{C\} \rightarrow \{D\}$
$\{D\} \rightarrow \{A\}$.

(3) Yes it is 2NF and 3NF (because all attributes are prime attributes). However, it is not BCNF (e.g., $\{C\} \rightarrow \{D\}$ and $\{D\} \rightarrow \{A\}$).

(4) Omitted as it is 3NF.

Boss Level Extra - Case 3 (Solution)

(5) Decomposition at $\{C\} \rightarrow \{D\}$:

$R_1 = (A, \underline{C}, D)$,
$R_2 = (\underline{B}, \underline{C})$.

In this way both relations are BCNF, but we lose a dependency $\{A, B\} \rightarrow \{C\}$.

How about we change the entry point of decomposition?

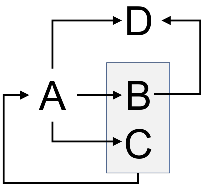
Decomposition at $\{D\} \rightarrow \{A\}$:

$R_1 = (A, \underline{D})$,
$R_2 = (B, \underline{C}, D)$.

In this way both relations are BCNF, but we (still) lose that dependency $\{A, B\} \rightarrow \{C\}$.

Boss Level Extra - Case 4

Another abstract relations with functional dependencies shown as in the figure below:



Questions:
(1) Find **candidate key(s)** and **prime attribute(s)** from attribute closures Σ^+.
(2) Compute the **compact minimal cover** of R with all FDs Σ.
(3) Determine if it is **2NF**? If yes, is it **3NF**? If yes, is it **BCNF**?
(4) If it is not 3NF, **synthesis** the relations to make it 3NF.
(5) If it is not BCNF, **decomposite** the relations to make it BCNF and verify the **dependency preservation**.

Boss Level Extra - Case 4 (Solution)

Solution:
(1) The attribute closure of $R = \{A, B, C, D\}$ is:

$$
\begin{aligned}
\Sigma^+ = \{&\{A\}^+ \rightarrow \{A, B, C, D\},\\
&\{B\}^+ \rightarrow \{B, D\},\\
&\{C\}^+ \rightarrow \{C\},\\
&\{D\}^+ \rightarrow \{D\},\\
&\{A, B\}^+ \rightarrow \{A, B, C, D\},\\
&\{A, C\}^+ \rightarrow \{A, B, C, D\}(\textit{trivial}),\\
&\{A, D\}^+ \rightarrow \{A, B, C, D\}(\textit{trivial}),\\
&\{B, C\}^+ \rightarrow \{A, B, C, D\}\\
&\{B, D\}^+ \rightarrow \{B, D\}, \ldots
\end{aligned}
$$

Now we find candidate keys: $\{A\}$ or $\{B, C\}$.
Prime attributes: A, B, C.

Boss Level Extra - Case 4 (Solution)

(2) The compact minimal cover is:

$\{A\} \rightarrow \{B, C, D\}$
$\{B\} \rightarrow \{D\}$
$\{B, C\} \rightarrow \{A\}$.

(3) No it is not 2NF (e.g., $\{B\} \rightarrow \{D\}$, where D is a non-prime attribute but B is a subset of candidate key). Therefore, it is not 3NF and not BCNF, too.

(4) Synthesis result has 2 relations and each one is (luckily) BCNF:

$R_1 = (\underline{A}, \underline{B, C}, D)$,
$R_2 = (\underline{B}, D)$,
$\cancel{R_3 = (\underline{B, C}, \underline{A})}$. (duplicate with R_1)

Boss Level Extra - Case 4 (Solution)

(5) Decomposition at $\{B\} \rightarrow \{D\}$:

$R_1 = (\underline{B}, D)$,
$R_2 = (\underline{A}, \underline{B, C})$.

In this way both relations are BCNF, but we lose a dependency $\{A\} \rightarrow \{D\}$.

Boss Level Extra - In-class Case 1

Given a relation $R = \{A, B, C\}$ with functional dependency set:
$\Sigma = \{\{A\} \rightarrow \{B\}, \{B\} \rightarrow \{C\}, \{A, B\} \rightarrow \{C\}, \{B, C\} \rightarrow \{A\}\}$.

Questions:
(1) Find **candidate key(s)** and **prime attribute(s)** from attribute closures Σ^+.
(2) Compute the **compact minimal cover** of R with all FDs Σ.
(3) Determine if it is **2NF**? If yes, is it **3NF**? If yes, is it **BCNF**?
(4) If it is not 3NF, **synthesis** the relations to make it 3NF.
(5) If it is not BCNF, **decomposite** the relations to make it BCNF and verify the **dependency preservation**.

Boss Level Extra - In-class Case 1 (Solution)

$R = \{A, B, C\}$
$\Sigma = \{\{A\} \to \{B\}, \{B\} \to \{C\}, \{A, B\} \to \{C\}, \{B, C\} \to \{A\}\}.$

Solution:
(1) The attribute closure of R is:

$$\begin{aligned}\Sigma^+ = \{&\{A\}^+ \to \{A, B, C\},\\ &\{B\}^+ \to \{A, B, C\},\\ &\{C\}^+ \to \{C\},\\ &\{A, B\}^+ \to \{A, B, C\},\\ &\{A, C\}^+ \to \{A, B, C\},\\ &\{B, C\}^+ \to \{A, B, C\},\\ &\{A, B, C\}^+ \to \{A, B, C\}\}.\end{aligned}$$

Now we find candidate keys: $\{A\}$ and $\{B\}$.
Prime attributes: A, B

Boss Level Extra - In-class Case 1 (Solution)

$$\Sigma = \{\{A\} \rightarrow \{B\}, \{B\} \rightarrow \{C\}, \{A, B\} \rightarrow \{C\}, \{B, C\} \rightarrow \{A\}\}.$$

(2) The minimal cover is:

$\{A\} \rightarrow \{B\}$,
$\{B\} \rightarrow \{C\}$,
$\{B, C\} \rightarrow \{A\}$.

This is the compact minimal cover, too.

(3) Yes it is 2NF, 3NF, and BCNF, too.

(4) Omitted as it is 3NF.

(5) Omitted as it is BCNF.

Boss Level Extra - In-class Case 2

Given a relation $R = \{A, B, C, D, E\}$ with functional dependency set: $\Sigma = \{\{C, D\} \rightarrow \{E\}, \{A, B\} \rightarrow \{B\}, \{A, C, D\} \rightarrow \{E\}, \{A\} \rightarrow \{E\}, \{D, E\} \rightarrow \{B, C\}, \{A\} \rightarrow \{A\}\}$.

Questions:
(1) Find **candidate key(s)** and **prime attribute(s)** from attribute closures Σ^+.
(2) Compute the **compact minimal cover** of R with all FDs Σ.
(3) Determine if it is **2NF**? If yes, is it **3NF**? If yes, is it **BCNF**?
(4) If it is not 3NF, **synthesis** the relations to make it 3NF.
(5) If it is not BCNF, **decomposite** the relations to make it BCNF and verify the **dependency preservation**.

Boss Level Extra - In-class Case 2 (Solution)

$\Sigma = \{\{C, D\} \to \{E\}, \{A, B\} \to \{B\}, \{A, C, D\} \to \{E\}, \{A\} \to \{E\}, \{D, E\} \to \{B, C\}, \{A\} \to \{A\}\}$.

Solution:

(1) The attribute closure of R is:

$$\begin{aligned}
\Sigma^+ = \{&\{A\}^+ \to \{A, E\},\\
&\{B\}^+ \to \{B\},\\
&\{C\}^+ \to \{C\},\\
&\{D\}^+ \to \{D\},\\
&\{E\}^+ \to \{E\},\\
&\{A, B\}^+ \to \{A, B, E\},\\
&\{A, C\}^+ \to \{A, C, E\},\\
&\{A, D\}^+ \to \{A, D\},\\
&\{A, E\}^+ \to \{A, B, E\}\}\\
&\ldots\\
&\{A, C, D, E\}^+ \to \{A, B, C, D, E\}\}\\
&\{A, B, C, D, E\}^+ \to \{A, B, C, D, E\}\}.
\end{aligned}$$

Hint:

After removing all trivial FDs, we find A and D have never appeared in the right-hand side, which means the candidate key must contains A and D. We just need to find the minimal set that implies $\{B, C, E\}$.

Then we can find candidate key: $\{A, C, D, E\}$.
Prime attributes: A, C, D, E

Boss Level Extra - In-class Case 2 (Solution)

$\Sigma = \{\{C, D\} \rightarrow \{E\}, \{A, B\} \rightarrow \{B\}, \{A, C, D\} \rightarrow \{E\}, \{A\} \rightarrow \{E\}, \{D, E\} \rightarrow \{B, C\}, \{A\} \rightarrow \{A\}\}$.

(2) The compact minimal cover is:

$\{C, D\} \rightarrow \{E\}$,
$\cancel{\{A, B\} \rightarrow \{B\}}$,
$\cancel{\{A, C, D\} \rightarrow \{E\}}$,
$\{A\} \rightarrow \{E\}$,
$\{D, E\} \rightarrow \{B\}$.
$\{D, E\} \rightarrow \{C\}$.
$\cancel{\{A\} \rightarrow \{A\}}$

$\rightarrow$

So the finalized set is:
$\{C, D\} \rightarrow \{E\}$,
$\{A\} \rightarrow \{E\}$,
$\{D, E\} \rightarrow \{B\}$.
$\{D, E\} \rightarrow \{C\}$.

(3) No it is not 2NF, not 3NF, and not BCNF, too.

$\{D, E\} \rightarrow \{B\}$ violates 2NF.
$\{D, E\} \rightarrow \{B\}$ violates 3NF.
All FDs in minimal cover violate BCNF.

Boss Level Extra - In-class Case 2 (Solution)

(4) Recall the compact minimal cover:

$\{C, D\} \rightarrow \{E\}$,
$\{A\} \rightarrow \{E\}$,
$\{D, E\} \rightarrow \{B\}$.
$\{D, E\} \rightarrow \{C\}$.

Let's do 3NF synthesis:

$$\begin{aligned} R_1 &= (\underline{C, D}, E), \\ R_2 &= (\underline{A}, E), \\ R_3 &= (B, \underline{D, E}). \\ R_4 &= (C, \underline{D, E}). \\ R_5 &= (\underline{A, C, D, E}). \end{aligned} \quad \rightarrow \quad \begin{aligned} &\text{So the simplified result is:} \\ R_1 &= (\underline{A, C, D, E}), \\ R_2 &= (B, \underline{D, E}), \end{aligned}$$

Both relation are BCNF.

Boss Level Extra - In-class Case 2 (Solution)

(5) Recall the compact minimal cover:
$\{C, D\} \rightarrow \{E\}$,
$\{A\} \rightarrow \{E\}$,
$\{D, E\} \rightarrow \{B\}$.
$\{D, E\} \rightarrow \{C\}$.

Decomposition at $\{C, D\} \rightarrow \{E\}$:

$R_1 = (\underline{C, D}, E)$,
$R_2 = (\underline{A}, B, \underline{C, D})$.

We can find that:

$\Sigma_1 = \{\{C, D\} \rightarrow \{E\}\}$ $\Sigma_2 = \emptyset$
Both relations are BCNF

However, we lose lots of dependency in this decomposition.

For any further question, please feel free to email me:

huasong.meng@u.nus.edu