CSEP514 Section5:

• Conceptual Schema Design

• Functional Dependency & BCNF
Part I --- Conceptual Design

Normal forms and functional dependencies:

- **Anomalies** (redundancy, update/deletion anomalies), functional dependencies, attribute closures, BCNF decomposition

![Conceptual Model](image)

- The BCNF (Boyce-Codd Normal Form) ---- A relation R is in BCNF if every set of attributes is either a superkey or its closure is the same set.
Example 1.

Consider the following relational schema and set of functional dependencies. $R(A,B,C,D,E,F,G)$ with functional dependencies:

- $A \rightarrow D$
- $D \rightarrow C$
- $F \rightarrow EG$
- $DC \rightarrow BF$

Decompose $R$ into BCNF.
Example 1 -- Solution.

\[ R(A, B, C, D, E, F, G) \]

- \( A \rightarrow D \)
- \( D \rightarrow C \)
- \( F \rightarrow EG \)
- \( DC \rightarrow BF \)

**Solution:** Watch-out! The first FD does NOT violate BCNF so we need to pick another one to decompose. We try the second one:

Try \( \{ D \}^+ = \{ B, C, D, E, F, G \} \). Decompose into \( R1(B, C, D, E, F, G) \) and \( R2(A, D) \).

\( R2 \) has two attributes, so it is necessarily in BCNF.

For \( R1 \), again not all FDs violate BCNF so we need to be careful.

Try \( \{ F \}^+ = \{ E, F, G \} \). Decompose into \( R11(E, F, G) \) and \( R12(B, C, D, F) \).

Both \( R11 \) and \( R12 \) are in BCNF.
Example 2.

Relation $R(A,B,C,D,E,F)$ and functional dependencies:

$A \rightarrow BC$ and $D \rightarrow AF$

Decompose $R$ into BCNF.
Example 2 -- Solution.

Relation $R(A, B, C, D, E, F)$ and FD’s $A \rightarrow BC$ and $D \rightarrow AF$

$A \rightarrow BC$ violates BCNF since $A^+ = ABC \neq ABCDEF$. So we split $R$ into $R1(ABC)$ and $R2(ADEF)$.

The only non-trivial FD in $R1$ is $A \rightarrow BC$, and $A^+ = ABC$, so $R1$ is in BCNF.

$R2$ has a non-trivial dependency $D \rightarrow AF$ that violates BCNF because $D^+ = ADF \neq ADEF$. So we split $R2$ into $R21(DAF)$ and $R22(DE)$. Both of these are in BCNF since they have no non-trivial dependencies that are not superkeys.
Example 3

Relational schema: $R(A,B,C,D,E)$,
functional dependencies:  $AB \rightarrow C$,  $BC \rightarrow D$

Decompose $R$ into BCNF.
Example 3 -- solution

Relational schema: $R(A, B, C, D, E)$,
functional dependencies: $AB \rightarrow C$, $BC \rightarrow D$

First step uses $BC^+ = BCD$ and decomposes into $R1(B, C, D)$, $R2(A, B, C, E)$; second step decomposes $R2$ into $R3(A, B, C)$ and $R4(A, B, E)$
Example 4

The relation is $R \ (A, B, C, D, E)$ and the FDs:
$A \rightarrow E$, $BC \rightarrow A$, and $DE \rightarrow B$

Decompose $R$ into BCNF.
Example 4 – solution 1

The relation is $R(A, B, C, D, E)$ and the FDs: $A \rightarrow E$, $BC \rightarrow A$, and $DE \rightarrow B$

Notice that $\{A\}^+ = \{A,E\}$, violating the BCNF condition. We split $R$ to $R_1(A,E)$ and $R_2(A,B,C,D)$.

$R_1$ satisfies BCNF now, but $R_2$ not because of: $\{B,C\}^+ = \{B,C,A\}$. Notice that the fd $D \rightarrow B$ has now disappeared and we don't need to consider it! Split $R_2$ to: $R_2A(B,C,A)$ and $R_2B(B,C,D)$. 
Example 4 – solution 2

The relation is \( R \ (A, B, C, D, E) \) and the FDs:
\[ A \rightarrow E, \ BC \rightarrow A, \ \text{and} \ DE \rightarrow B \]

Can we split differently? Let's try with the violation \( \{B,C\}^+ = \{B,C,A,E\} \). We initially split to \( R_1(B,C,A,E) \) and \( R_2(B,C,D) \). Now we need to resolve for \( R_1 \) the violation \( \{A\}^+ = \{A,E\} \). So we split again \( R_1 \) to \( R_{1A}(A,E) \) and \( R_{1B}(A,B,C) \). The same!

We can also start splitting by considering the BCNF violation \( \{D,E\}^+ = \{D,E,B\} \). Which is the resulting BCNF decomposition in this case? (it will be a different one)