Lossless Join Decomposition Tutorial

SWEN304/SWEN435

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Outline

- Lossless join decomposition
- Exercises
  - 3NF decomposition
  - BCNF decomposition

FDs and a Relation Schema Key

- Each relation schema **key** is the consequence of a functional dependency from F^+
- Let $R(A_1, \ldots, A_n)$ be a relation schema and F the set of functional dependencies in R
- Set of attributes $X \subseteq R$ is a relation schema **key** if

$1^o\ X \rightarrow R \in F^+$ (or $X^+ = R$)

$2^o\ (\forall Y \subset X)(Y \rightarrow R \notin F^+)$

- Not null condition still applies to X
- A **prime** attribute is a relation schema attribute that belongs to any of the keys
- Primary key is one of the keys

Lossless Join Decomposition

- A decomposition D = $\{R_1, R_2, \ldots, R_m\}$ of a relation R has the **lossless (nonadditive) join** property wrt the set of dependencies *F* on *R* if, for every relation *r(R)* that satisfies *F*,

$$* (\pi_{R1} r(R) , \ldots , \pi_{Rm} r(R)) = r(R)$$

where * is the natural join of all the relations in D.

- It is proven in the theory of the relational data model that the decomposition of a relation schema *R* onto R_1 and R_2 is *lossless (non-additive)* if the intersection $R_1 \cap R_2$ contains a **key** of R_1 or a key of R_2

Example 1: Checking Losslessness of D (1)

- Given a set of relation schemas:

$D = \{N_1(\{A, B\}, \{A\}), N_2(\{B, D\}, \{B\}), N_3(\{C, B\}, \{C\})\}$

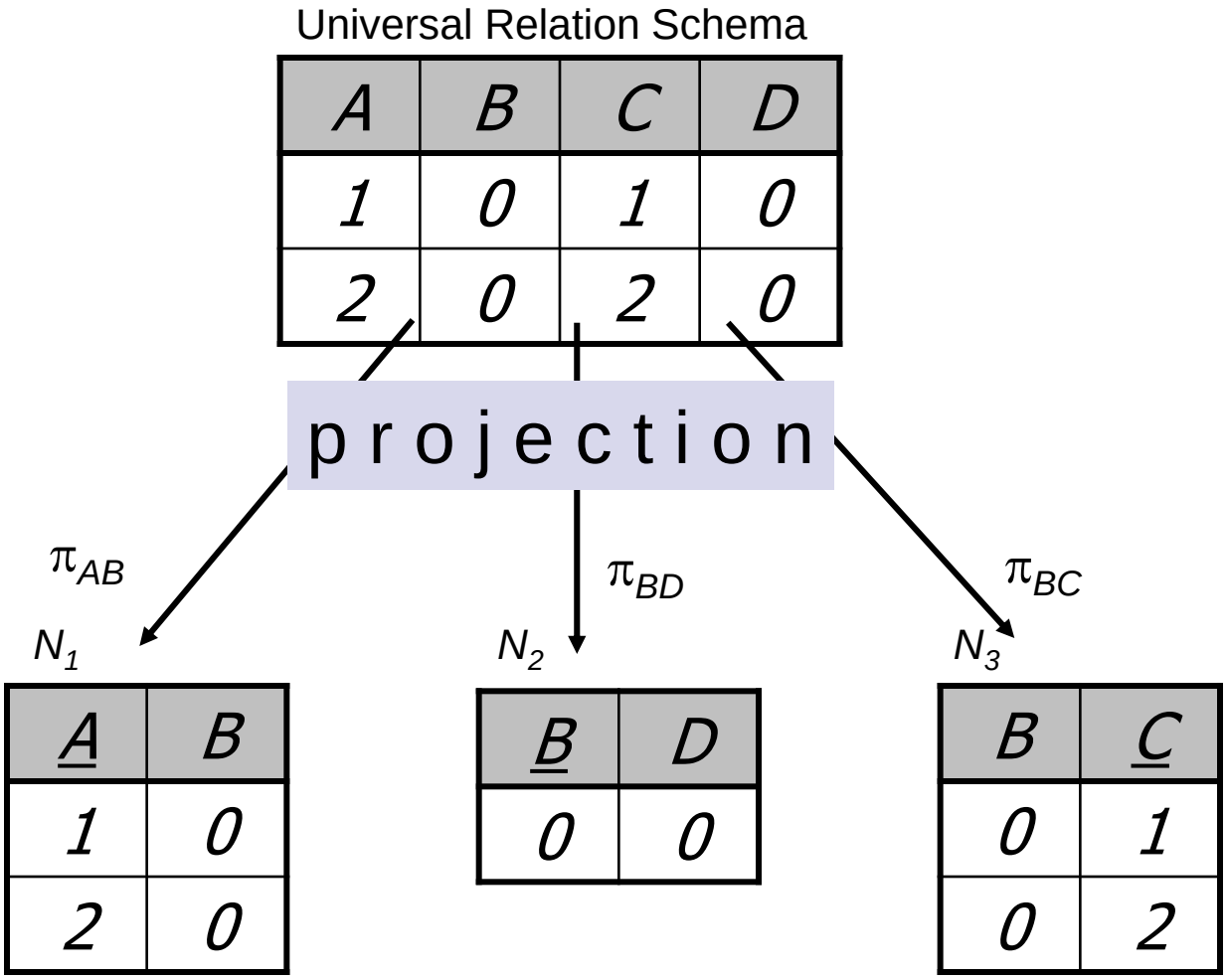
- How to check whether the whole set of relation schemas represents a lossless join decomposition of the (supposed) universal relation schema?

Example 1: Checking Losslessness of D (2)

- A naïve and generally **wrong** approach:
  - Perform a pair wise checking of the relation schemas
    - for each relation schema you find another one such that the intersection of the two schemas is a schema key of one of the schema

- So, according to that approach:
  - $\{A, B\} \cap \{B, D\} = \{B\}$, and B is the key of N_2
  - $\{B, C\} \cap \{B, D\} = \{B\}$, and B is the key of N_2
  - Conclusion (a wrong one): The set of relation schemas D is a lossless join decomposition (of a universal relation schema)

Example 1: Checking Losslessness of D (3)



Example 1: Checking Losslessness of D (4)

N_1

A	B
1	0
2	0

N_2

B	D
0	0

The pair wise approach is wrong since

- It can not ensure the whole decomposition is lossless

N_3

B	C
0	1
0	2

Natural Join $r(N_1)*r(N_2)$

A	B	D
1	0	0
2	0	0

$(r(N_1)*r(N_2))*r(N_3)$

A	B	C	D
1	0	1	0
1	0	2	0
2	0	1	0
2	0	2	0

Example 1: Checking Losslessness of D (5)

$$D = \{N_1(\{A, B\}, \{A\}), N_2(\{B, D\}, \{B\}), N_3(\{C, B\}, \{C\})\}$$

- A correct approach is to apply this checking iteratively until all the schemas are considered
  - $\{A, B\} \cap \{B, D\} = \{B\}$, and B is the key of N_2,
  - construct new relation schema N_{12} (R_{12}, Key(N_{12})), with R_{12}= $\{A, B\} \cup \{B, D\} = \{A, B, D\}$ and Key(N_{12}) =$\{A\}$

  - $\{A, B, D\} \cap \{B, C\} = \{B\}$, and check again.
  - B is neither a key of N_{12} nor a key of N_3

- We can conclude the set of relation schemas D is a not a lossless join decomposition (of a universal relation schema).

One Approach of Checking Losslessness of D

- To check whether a set D of relation schemas is a lossless decomposition is:
  1. Construct a relation schema (U, F), where
  $$U = \bigcup_{i=1}^{n} R_i \quad \text{and} \quad F = \bigcup_{i=1}^{n} F_i$$
  2. Find all keys $\{X_i \mid i = 1, \ldots, m\}$ of the constructed "universal" relation schema (U, F)
  3. If there is a relation schema $M(R, K)$ in D that contains a key of the constructed relation schema (U, F), then D is a lossless join decomposition
  4. Otherwise, add a new relation schema that contains only a key X_i of the constructed "universal" relation schema (U, F) to D
  $$D = D \cup \{N_x(X_i, X_i)\}$$

Example 2: Checking Losslessness of D

- The universal relation schema key is *AC*, and decompositions

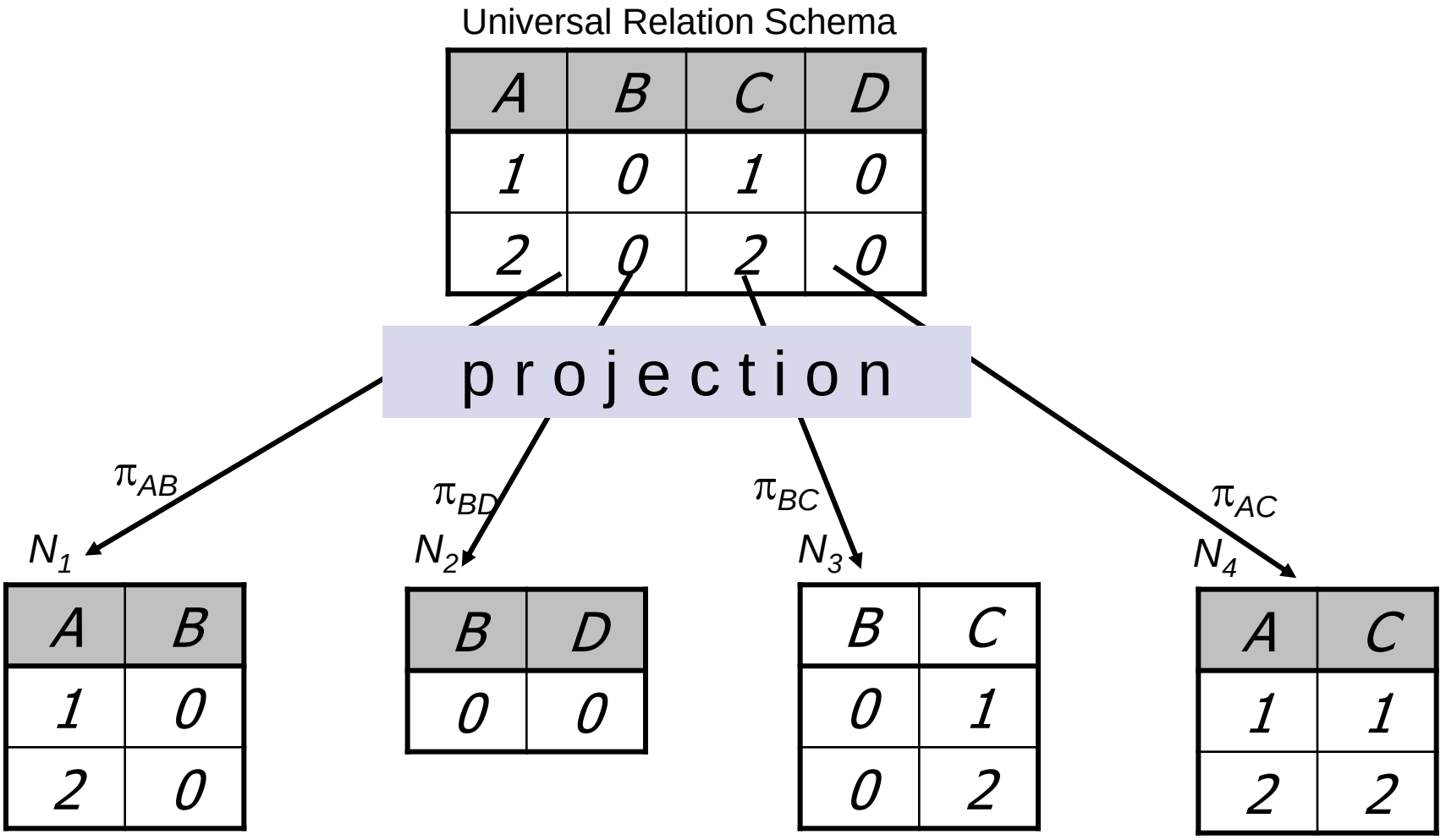
  $D = \{N_1(\{A, B\}, \{A\}), N_2(\{B, D\}, \{B\}), N_3(\{B, C\}, \{C\}))\}$

  Is the decomposition lossless? Why?
- No, since none of them contains schema key AC

- A lossless decomposition

  $D' = \{N_1(\{A, B\}, \{A\}), N_2(\{B, D\}, \{B\}), N_3(\{B, C\}, \{C\}),$
  $N_4(\{A, C\}, \{AC\})\}$
- This can be achieved using the Synthesis Algorithm

Example 2: Checking Losslessness of D (3)



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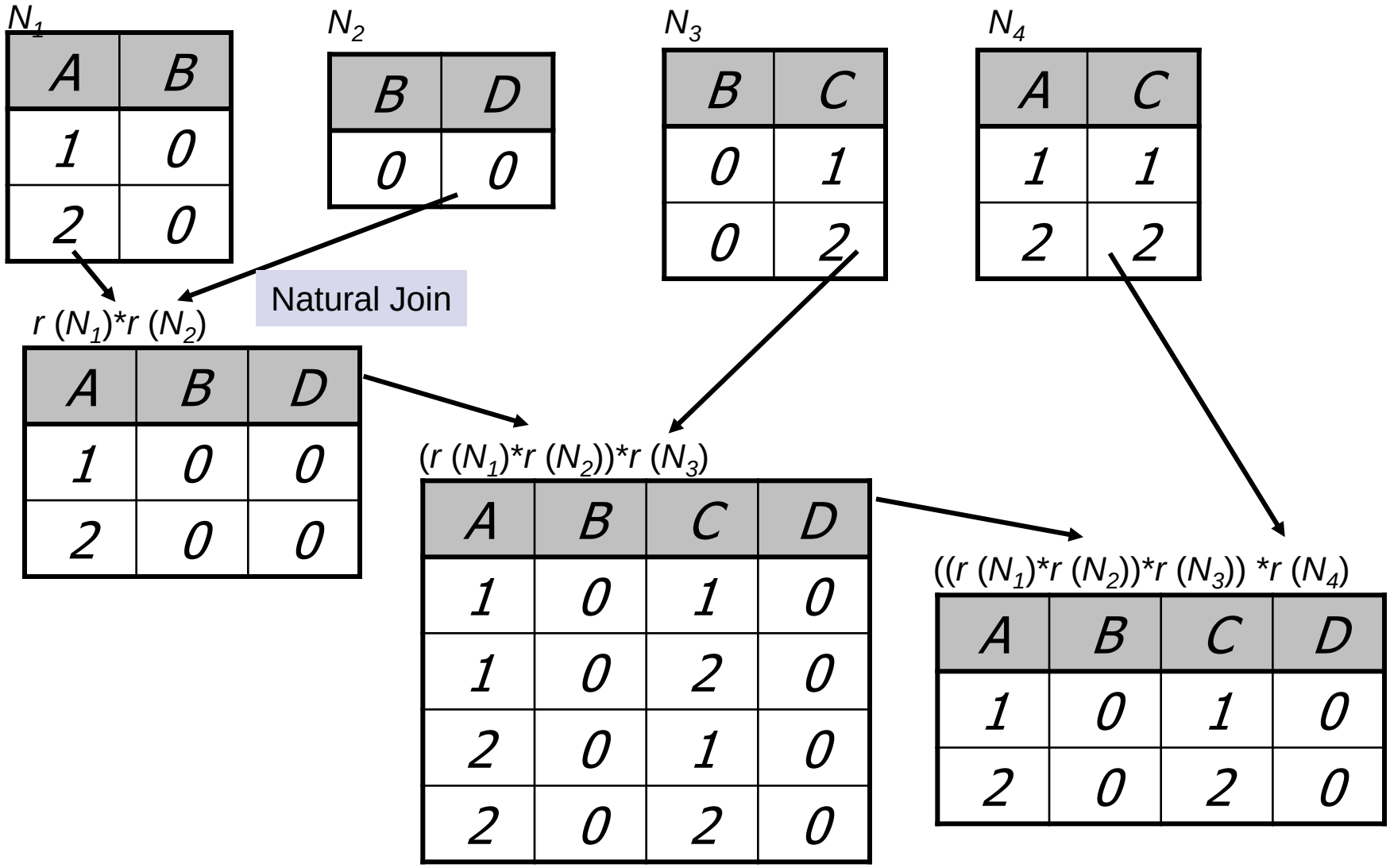

Exercise 1: Lossless Join Decomposition

- Consider the following relation schema again

  Department ({*LecId*, *LeName*, *CourId*, *CoName*, *DptId* },
  {*LecId* $\rightarrow$ *LeName* + *CourId*, *CourId* $\rightarrow$ *CoName* + *DptId* })

a) Is Department in 3NF? If not, decompose it into 3NF
b) Is Department in BCNF? If not, decompose it into BCNF

Exercise 2: Find Keys and Normalization

- Let $R = ABCD$ a relation schema and $F = \{AB \rightarrow C, C \rightarrow D, D \rightarrow A\}$ a set of dependencies for R.

1) Find the candidate keys for R
2) If R is not in BCNF, give a decomposition of R in relations that will be in BCNF

Exercise 3: Find Keys and Normalization

- Let $R=JKL$ a relation and $F = \{JK \rightarrow L, L \rightarrow K\}$ a set of dependencies for R.

1) Find two candidate keys in R
2) Is R in 3NF? Justify your answer
3) If R is not in BCNF, decompose R into BCNF
4) Are the functional dependencies preserved during the decomposition?