CS448 PSO
Week 4

CS448 staff

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3NF and BCNF

- FD: $X \to A$ is **nontrivial** (RHS attribute is not in LHS)
- 3NF: a relation R is in **3NF** iff (if and only if) for every nontrivial FD $X \to A$, either:
  - X is a **superkey**, or
  - A is **prime** (member of at least one key)
- BCNF: a relation R is in **BCNF** if for every nontrivial FD of R, say $X \to A$,
  - X is a **superkey**, or
  - ~~A is **prime** (member of at least one key)~~

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Example

- Consider the relation
  - $\text{Contracts}(\underline{\text{contractId}}, \text{supplierId, projectId, deptId, partId, qty, value})$
  - We will denote this relation schema by listing the attributes $CSJDPQV$
- Functional dependencies
  - C is the key
    - $C \to CSJDPQV$
  - Project purchases each part using single contract
    - $JP \to C$
  - Dept purchases at most one part from a supplier
    - $SD \to P$
  - Each project deals with a single supplier
    - $J \to S$

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Example 1: decompose a schema into BCNF

- Schema: CSJDPQV
- FDs: {SD→P, J→S, JP→C}
- FDs violate BCNF

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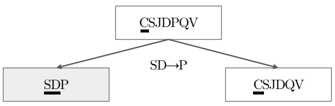
Example 1: decompose a schema into BCNF

- Schema: CSJDPQV
- FDs: {SD→P, J→S, JP→C}
- FDs violate BCNF

SD is not a key,
SD→P causes violation of BCNF



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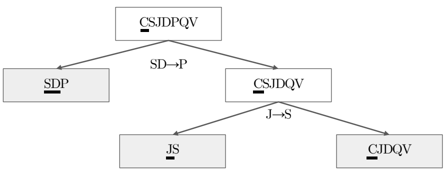
Example 1: decompose a schema into BCNF

- Schema: CSJDPQV
- FDs: {SD→P, J→S, JP→C}
- FDs violate BCNF

J is not a key,
J→S causes violation of BCNF



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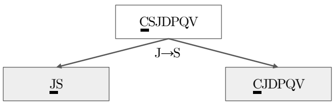
Alternatives in decomposing into BCNF

- Schema: CSJDPQV
- FDs: {SD→P, J→S, JP→C}
- FDs violate BCNF

Order in which we deal with the FDs, can lead to very different sets of relations



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Which alternative should be used?

Choose the alternatives based on the semantics of the application.
Example:

R=(course id, course name, course abbreviation, year, instructor)
- course abbreviation → course name
- course name, year → instructor

- The most frequently used query:
  - selecting instructors given the course name and year.
- Two decompositions:
  - (course name, course abbreviation) and (course id, course abbreviation, year, instructor)
  - (course name, year, instructor) and (course id, course name, course abbreviation, year)

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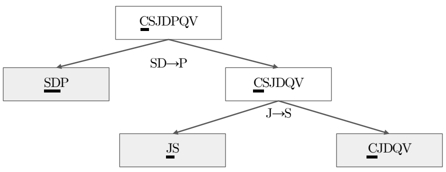
Example 1: decompose a schema into BCNF

Decomposed schema: SDP, JS, CJDQV

✓ lossless join decomposition

✗ dependency preserving decomposition



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Example 2: dependency-preserving decomposition into 3NF

- Schema: CSJDPQV
- FDs: {SD→P, J→S, JP→C}
- SD→P, J→S violate 3NF

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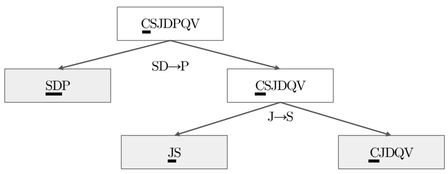
Example 2: dependency-preserving decomposition into 3NF

- Schema: CSJDPQV
- FDs: {SD→P, J→S, JP→C}
- SD→P, J→S violate 3NF

Dependency JP→C is not preserved



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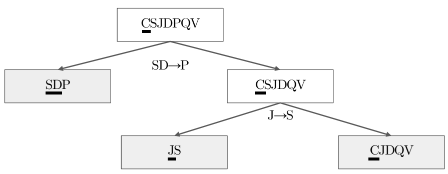
Example 2: dependency-preserving decomposition into 3NF

- Schema: CSJDPQV
- FDs: {SD→P, J→S, JP→C}
- SD→P, J→S violate 3NF

Add a relation schema: CJP



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Create views to consolidate a non-preserved FD

- Use materialized views to consolidate a non-preserved FD into one table
- Check the FD in that materialized view by making LHS of the FD the key for the view
- But will need to maintain the views when the base tables get updated

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3NF synthesis

- Take all the attributes over the original relation R and a minimal cover F for the FDs that hold over it, and add a relation schema XA to the decomposition of R for each FD $\mathrm{X} \rightarrow \mathrm{A}$ in F.
- If no decomposed table contains a candidate key for R, add a relation schema of any candidate key for R.

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Minimal cover

Minimal (Canonical) Cover for a set F of FDs is a set G of FDs such that:

1. Every dependency in G is of the form $\mathrm{X} \rightarrow \mathrm{A}$, where A is a single attribute
2. The closure F^+ is equal to the closure G^+
3. If we obtain a set H of dependencies from G by deleting one or more dependencies or by deleting attributes from a dependency in G, then $\mathrm{F}^+ \neq \mathrm{H}^+$

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Example 3: find the minimal cover set

Let F be the set of dependencies:

$A \rightarrow B$, $ABCD \rightarrow E$, $EF \rightarrow G$, $EF \rightarrow H$, $ACDF \rightarrow EG$

1. Rewrite $ACDF \rightarrow EG$ to: $ACDF \rightarrow E$, $ACDF \rightarrow G$
2. Delete $ACDF \rightarrow G$ (redundant), implied by $A \rightarrow B$, $ABCD \rightarrow E$, $EF \rightarrow G$)
3. Delete $ACDF \rightarrow E$ (redundant)
4. Minimize left side of $ABCD \rightarrow E$ to $ACD \rightarrow E$, since $A \rightarrow B$ holds

Thus, a minimal cover for F is the set:

$A \rightarrow B$, $ACD \rightarrow E$, $EF \rightarrow G$, $EF \rightarrow H$

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General algorithm for obtaining a minimal cover set

1. Put the FDs in a standard form (single attribute on the right)
2. Minimize the left side of each FD
3. Delete redundant FDs

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Example 4: 3NF synthesis

- Schema: $\underline{C}SJDPQV$
- FDs: $\{C \rightarrow CSJDPQV$, $JP \rightarrow C$, $SD \rightarrow P$, $J \rightarrow S\}$

➢ Find the minimal cover set

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Example 4: 3NF synthesis

- Schema: $\underline{C}SJDPQV$
- FDs: $\{\boxed{C\to CSJDPQV,}\ JP\to C,\ SD\to P,\ J\to S\}$
- ➢ Find the minimal cover set

$$\boxed{C\to S,\ C\to J,\ C\to D,\ C\to P,\ C\to Q,\ C\to V,}\ JP\to C,\ SD\to P,\ J\to S$$

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Example 4: 3NF synthesis

- Schema: $\underline{C}SJDPQV$
- FDs: $\{C\to CSJDPQV,\ JP\to C,\ SD\to P,\ J\to S\}$
- ➢ Find the minimal cover set

$$\underline{C\to S},\ C\to J,\ \underline{C\to D},\ \boxed{C\to P}\ C\to Q,\ C\to V,\ JP\to C,\ \underline{SD\to P},\ J\to S$$

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Example 4: 3NF synthesis

- Schema: $\underline{C}SJDPQV$
- FDs: $\{C\to CSJDPQV,\ JP\to C,\ SD\to P,\ J\to S\}$
- ➢ Find the minimal cover set

$$\boxed{C\to S,}\ \underline{C\to J},\ C\to D,\ \cancel{C\to P},\ C\to Q,\ C\to V,\ JP\to C,\ SD\to P,\ \underline{J\to S}$$

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Example 4: 3NF synthesis

- Schema: CSJDPQV
- FDs: {C→CSJDPQV, JP→C, SD→P, J→S}
- ➢ Find the minimal cover set

  ~~C→S~~, C→J, C→D, ~~C→P~~, C→Q, C→V, JP→C, SD→P, J→S

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Example 4: 3NF synthesis

- Schema: CSJDPQV
- FDs: {C→CSJDPQV, JP→C, SD→P, J→S}
- ➢ Find the minimal cover set

  ~~C→S~~, C→J, C→D, ~~C→P~~, C→Q, C→V, JP→C, SD→P, J→S

- ➢ Schemas: CJ, CD, CQ, CV, SDP, JS, JPC
- ➢ (Optional) Combine: CJDQVP, SDP, JS
- ➢ CJDQVP is a superkey

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Case Study: The Internet shop

Relations:

- Books (isbn, title, author, qty_in_stock, price, year_published)
- Customers (cid, cname, address)
- Orders (ordernum, isbn, cid, cardnum, qty, order_date, ship_date)

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Case Study: The Internet shop

Relations:
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- Customers(cid, cname, address)
- Orders(ordernum, isbn, cid, cardnum, qty, order_date, ship_date)

Functional Dependencies:
- Books has one key: isbn. No other FDs
- Customers has one key: cid. No other FDs
- Orders has key: (ordernum, isbn).
  Other FDs: ordernum→cid, ordernum→order_date, ordernum→cardnum

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Decomposition

- Schema: Orders(ordernum, isbn, cid, cardnum, qty, order_date, ship_date)
- FDs: ordernum→cid, ordernum→order_date, ordernum→cardnum

Orders

ordernum, isbn, cid, cardnum, qty, order_date, ship_date

ordernum→cid, order_date, cardnum

ordernum, cid, order_date, cardnum

Orders

ordernum, isbn, qty, ship_date

Orderlists

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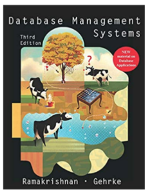
References

1. "The cow book": Database management systems by Raghu Ramakrishnan and Johannes Gehrke



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