ICS 321 Fall 2009

# Schema Refinement & Normal Forms (iii)

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# Decompositions

- Reduces redundancies and anomalies, but could have the following potential problems:
  - Some queries become more expensive.
  - Given instances of the decomposed relations, we may not be able to reconstruct the corresponding instance of the original relation!
  - Checking some dependencies may require joining the instances of the decomposed relations.
- Two desirable properties:
  - Lossless-join decomposition
  - Dependency-preserving decomposition

# Lossless-join Decomposition

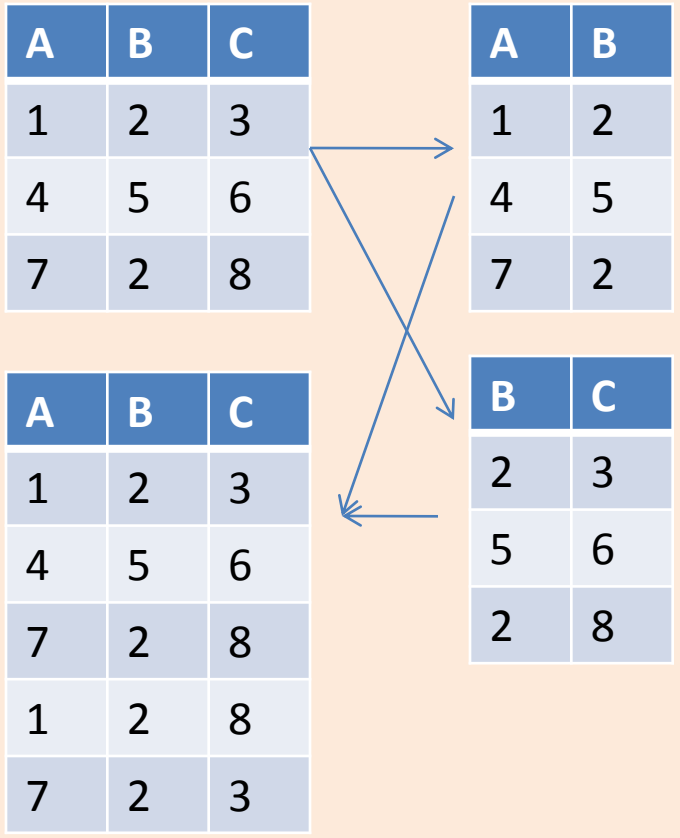
- Decomposition of R into X and Y is *lossless-join* w.r.t. a set of FDs F if, for every instance *r* that satisfies F:

$$\pi_X(r) \text{ join } \pi_Y(r) = r$$

- In general one direction $\pi_X(r) \text{ join } \pi_Y(r) \supseteq r$ is always true, but the other may not hold.
- Definition extended to decomposition into 3 or more relations in a straightforward way.
- *It is essential that all decompositions used to deal with redundancy be lossless! (Avoids Problem (2).)*

# Conditions for Lossless Join

- The decomposition of R into X and Y is lossless-join wrt F if and only if the closure of F contains:
  - $X \cap Y \rightarrow X$, or
  - $X \cap Y \rightarrow Y$
- In particular, the decomposition of R into UV and R - V is lossless-join if $U \rightarrow V$ holds over R.



| A | B | C |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 5 | 6 |
| 7 | 2 | 8 |

| A | B |
|---|---|
| 1 | 2 |
| 4 | 5 |
| 7 | 2 |

| A | B | C |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 5 | 6 |
| 7 | 2 | 8 |
| 1 | 2 | 8 |
| 7 | 2 | 3 |

| B | C |
|---|---|
| 2 | 3 |
| 5 | 6 |
| 2 | 8 |

# Dependency-preserving Decomposition

| Student | Course | Instructor |
|---|---|---|
| Smith | OS | Mark |

→

| Student | Instructor |
|---|---|
| Smith | Mark |

| Course | Instructor |
|---|---|
| OS | Mark |

F= { SC → I, I→C }

Checking SC → I requires a join!

- Dependency preserving decomposition (Intuitive):
  - If R is decomposed into X, Y and Z, and we enforce the FDs that hold on X, on Y and on Z, then all FDs that were given to hold on R must also hold. *(Avoids Problem (3).)*
- *Projection of set of FDs F*: If R is decomposed into X, ... projection of F onto X (denoted $F_X$ ) is the set of FDs U → V in $F^+$ (*closure of F* ) such that U, V are in X.

# Dependency-preserving Decomp. (Cont)

- Decomposition of R into X and Y is *dependency preserving* if $(F_X \text{ union } F_Y)^+ = F^+$
  - i.e., if we consider only dependencies in the closure $F^+$ that can be checked in X without considering Y, and in Y without considering X, these imply all dependencies in $F^+$.
- Important to consider $F^+$, not F, in this definition:
  - ABC, $A \rightarrow B$, $B \rightarrow C$, $C \rightarrow A$, decomposed into AB and BC.
  - Is this dependency preserving? Is $C \rightarrow A$ preserved?????
- Dependency preserving does not imply lossless join:
  - ABC, $A \rightarrow B$, decomposed into AB and BC.
- And vice-versa! (Example?)

# Decomposition into BCNF

- Consider relation R with FDs F. How do we decompose R into a set of small relations that are in BCNF ?
- Algorithm:
  - If $X \rightarrow Y$ violates BCNF, decompose R into R-Y and XY
  - Repeat until all relations are in BCNF.
- Example: CSJDPQV, key C, $JP \rightarrow C$, $SD \rightarrow P$, $J \rightarrow S$
  - To deal with $J \rightarrow S$, decompose CSJDPQV into JS and CJDPQV
  - To deal with $SD \rightarrow P$, decompose into SDP, CSJDQV
- Order in which we deal with the violating FD can lead to different relations!

# BCNF & Dependency Preservation

- BCNF decomposition is lossless join, but there may not be a dependency preserving decomposition into BCNF
  - e.g., CSZ, CS→Z, Z→C
  - Can't decompose while preserving 1st FD; not in BCNF.
- Similarly, decomposition of CSJDQV into SDP, JS and CJDQV is not dependency preserving (w.r.t. the FDs JP C, SD→P and J →S).
  - However, it is a lossless join decomposition.
  - In this case, adding JPC to the collection of relations gives us a dependency preserving decomposition.
    - JPC tuples stored only for checking FD! (*Redundancy!*)

# Decomposition into 3NF

- Obviously, the algorithm for lossless join decomp into BCNF can be used to obtain a lossless join decomp into 3NF (typically, can stop earlier).
- How can we ensure dependency preservation ?
  - If $X \rightarrow Y$ is not preserved, add relation XY.
  - Problem is that XY may violate 3NF! e.g., consider the addition of CJP to `preserve' $JP \rightarrow C$. What if we also have $J \rightarrow C$ ?
- Refinement: Instead of the given set of FDs F, use a *minimal cover for F*.

# Minimum Cover for a Set of FDs

- *Minimal cover* G for a set of FDs F:
  - Closure of F = closure of G.
  - Right hand side of each FD in G is a single attribute.
  - If we modify G by deleting an FD or by deleting attributes from an FD in G, the closure changes.
- Intuitively, every FD in G is needed, and ``*as small as possible*'' in order to get the same closure as F.
- e.g., A $\rightarrow$B, ABCD $\rightarrow$E, EF$\rightarrow$GH, ACDF $\rightarrow$EG has the following minimal cover:
  - A$\rightarrow$B, ACD$\rightarrow$E, EF$\rightarrow$ G and EF$\rightarrow$H

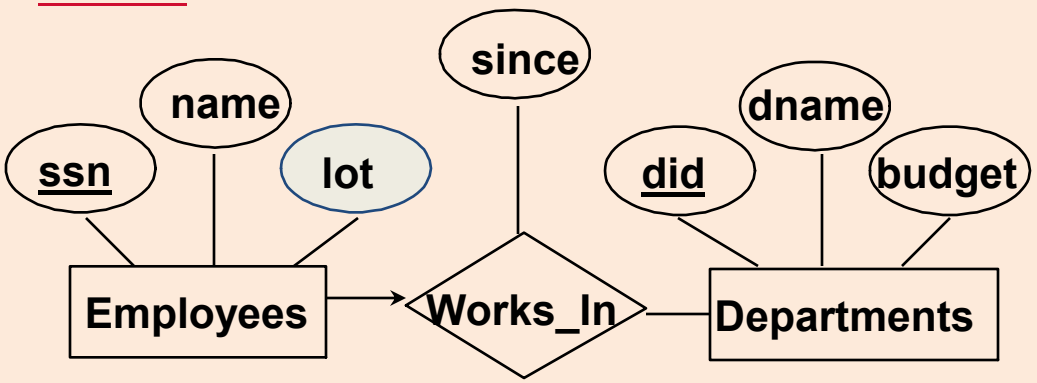
# Computing the Minimal Cover

- Algorithm
  1. **Put the FDs into standard form X → A**. RHS is a single attribute.
  2. **Minimize the LHS of each FD**. For each FD, check if we can delete an attribute from LHS while preserving $F^+$.
  3. **Delete redundant FDs**.
- Minimal covers are not unique. Different order of computation can give different covers.
- e.g., A →B, ABCD →E, EF→GH, ACDF →EG has the following minimal cover:
  - A→B, ACD→E, EF→ G and EF→H

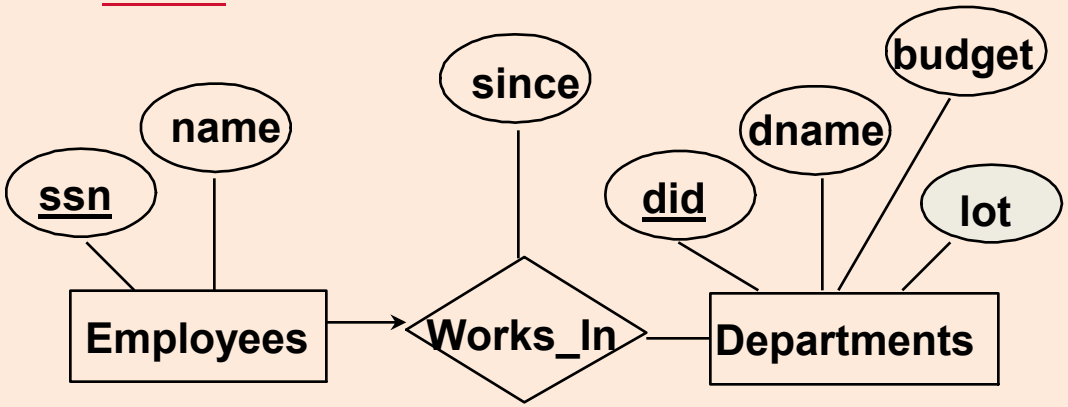
# Refining an ER Diagram

- 1st diagram translated:
  Workers(S,N,L,D,S)
  Departments(D,M,B)
  - Lots associated with workers
- Suppose all workers in a dept are assigned the same lot: D→L
- Redundancy; fixed by:
  Workers2(S,N,D,S)
  Dept_Lots(D,L)
- Can fine-tune this:
  Workers2(S,N,D,S)
  Departments(D,M,B,L)

Before:




After:



# Summary of Schema Refinement

- If a relation is in BCNF, it is free of redundancies that can be detected using FDs. Thus, trying to ensure that all relations are in BCNF is a good heuristic
- If a relation is not in BCNF, we can try to decompose it into a collection of BCNF relations.
  - Must consider whether all FDs are preserved. If a lossless-join, dependency preserving decomposition into BCNF is not possible (or unsuitable, given typical queries), should consider decomposition into 3NF.
  - Decompositions should be carried out and/or re-examined while keeping *performance requirements* in mind.