Normal Forms. BCNF and 3NF Decompositions

CS430/630
Lecture 17

Slides based on “Database Management Systems” 3rd ed, Ramakrishnan and Gehrke

Decomposition of a Relation Schema

- A ***decomposition*** of R replaces it by two or more relations
  - Each new relation schema contains a subset of the attributes of R
  - Every attribute of R appears in one of the new relations
  - E.g., SNLRWH decomposed into SNLRH and RW
- Decompositions should be used only when needed
  - Cost of join will be incurred at query time
- Problems may arise with (improper) decompositions
  - Reconstruction of initial relation may not be possible
  - Dependencies cannot be checked on smaller tables

Lossless Join Decompositions

- Decomposition of R into X and Y is ***lossless-join*** if:
  - $\pi_X(r) \bowtie \pi_Y(r) = r$

- It is always true that $r \subseteq \pi_X(r) \bowtie \pi_Y(r)$
  - In general, the other direction does not hold!
  - If it does, the decomposition is lossless-join.

- *It is essential that all decompositions used to deal with redundancy be lossless!*

Incorrect Decomposition

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

A	B
1	2
4	5
7	2

B	C
2	3
5	6
2	8

Natural Join

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

Condition 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.

Dependency Preserving Decomposition

- Consider CSJDPQV, C is key, JP $\rightarrow$ C and SD $\rightarrow$ P.
  - Consider decomposition: CSJDQV and SDP
  - Problem: Checking JP $\rightarrow$ C requires a join!
- Dependency preserving decomposition (Intuitive):
  - If R is decomposed into X and Y, and we enforce the FDs that hold on X, Y then all FDs that were given to hold on R must also hold

- *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 $\rightarrow$ V in F^+ (*closure of F*) such that U,V are in X.

Dependency Preserving Decompositions

- Decomposition of R into X and Y is ***dependency preserving*** if $(F_X \cup F_Y)^+ = F^+$
  - Dependencies that can be checked in X without considering Y, and in Y without considering X, together represent all dependencies in F^+

- Dependency preserving does not imply lossless join:
  - ABC, $A \rightarrow B$, decomposed into AB and BC.

Normal Forms

- If a relation is in a certain *normal form* (BCNF, 3NF etc.), it is known that certain kinds of problems are avoided/minimized.

- Role of FDs in detecting redundancy:
  - Consider a relation R with attributes AB
    - No FDs hold: There is no redundancy
    - Given $A \longrightarrow B$:
      - Several tuples could have the same A value
      - If so, they'll all have the same B value!

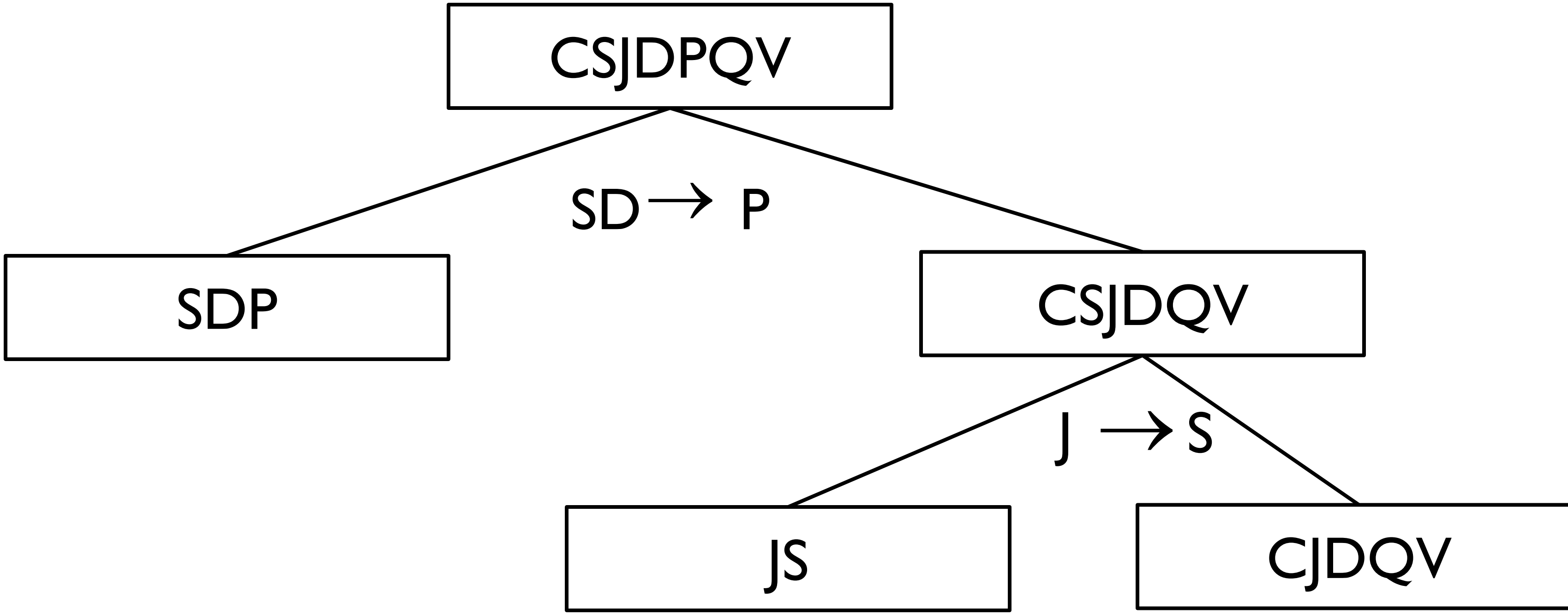
Boyce-Codd Normal Form (BCNF)

- Relation R with FDs *F* is in BCNF if, for all X$\rightarrow$ A in F^+
  - A $\subseteq$ X (called a *trivial* FD), or
  - X contains a key for R
- The only non-trivial FDs allowed are key constraints
- BCNF guarantees no anomalies occur

Decomposition into BCNF

- Consider relation R with FDs F. If $X \rightarrow Y$ violates BCNF, decompose R into R - Y and XY.
  - Repeated application of this idea will give us a collection of relations that are in BCNF; lossless join decomposition, and guaranteed to terminate.
  - e.g., CSJDPQV, key C, $JP \rightarrow C$, $SD \rightarrow P$, $J \rightarrow S$
  - To deal with $SD \rightarrow P$, decompose into SDP, CSJDQV.
  - To deal with $J \rightarrow S$, decompose CSJDQV into JS and CJDQV

Decomposition into BCNF



- In general, several dependencies may cause violation of BCNF. The order in which we "deal with" them could lead to very different sets of relations!

BCNF and Dependency Preservation

- In general, there may not be a dependency preserving decomposition into BCNF
  - e.g., $\underline{AB}C$, $AB \rightarrow C$, $C \rightarrow A$
  - Can't decompose while preserving first FD; not in BCNF

Third Normal Form (3NF)

- Relation R with FDs *F* is in 3NF if, for all X $\rightarrow$ A in F^+
  - A $\in$ X (called a *trivial* FD), or
  - X contains a key for R, or
  - A is part of some key for R (A here is a single attribute)
- *Minimality* of a key is crucial in third condition above!
- If R is in BCNF, it is also in 3NF.
- If R is in 3NF, some redundancy is possible
  - compromise used when BCNF not achievable
  - e.g., no ``good'' decomposition, or performance considerations
  - *Lossless-join, dependency-preserving decomposition of R into a collection of 3NF relations always possible.*

Decomposition into 3NF

- Lossless join decomposition algorithm also applies to 3NF
- To ensure dependency preservation, one idea:
  - If $X \rightarrow Y$ is not preserved, add relation XY
  - Refinement: Instead of the given set of FDs F, use a *minimal cover for F*
- Example: CSJDPQV, JP $\rightarrow$ C, SD $\rightarrow$ P, J $\rightarrow$ S
  - Choose SD $\rightarrow$ P, result is SDP and CSJDQV
  - Choose J $\rightarrow$ S, result is JS and CJDQV, all 3NF
  - Add CJP relation

Summary of Schema Refinement

- BCNF: relation is free of FD redundancies
  - Having only BCNF relations is desirable
  - If relation is not in BCNF, it can be decomposed to BCNF
    - Lossless join property guaranteed
    - But some FD may be lost
- 3NF is a relaxation of BCNF
  - Guarantees both lossless join and FD preservation
- Decompositions may lead to performance loss
  - *performance requirements* must be considered when using decomposition