CMPSC 174A/174N Fundamentals of Database System

Normal Form and Decomposition

Discussion Session
Friday, 9:00am-9:50am
Zexi Huang

Session 10

Schedule

- Checking Normal Forms
  - General Algorithm
  - Examples
- Decomposition into Normal Forms
  - General Algorithm
  - Examples

Checking Normal Forms

- **Problem**
  - For a relation ***R*** and a set of functional dependencies ***F***, find which normal form ***R*** is in.
  - Example: ***R***=(A,B,C), ***F***={A→B, B→C}. Is ***R*** in BCNF? Is ***R*** in 3NF?
- **Definition**
  - For every FD X→A in ***F***, one of the following is true:
    - A is a subset of X.
    - X is a superkey.
    - A is part of some key.
- **Algorithm**
  - Check for every FD X→A in ***F*** :
    - Is A a subset of X? (Is it trivial?)
    - Is X a superkey?
    - Is A part of a key?
  - If every FD satisfies the conditions above, then ***R*** is in corresponding normal form. Otherwise not.

Checking Normal Forms

- **Example 1.1**
  - ***R***=(A,B,C,D), ***F***={B→C, C→D, C→A}.
  - Is ***R*** in BCNF? Is ***R*** in 3NF?

- **Solution**
  - Identify all candidate keys:
    - B→C, C→D, C→A, *closure*(B)=ABCD. B is a candidate key.
    - Can we stop here?
    - Attribute set that doesn't contain B can't be candidate keys because nothing determines B.
    - B is the only candidate key.
  - Checking every non-trivial FD:
    - B→C:
      - Is B a superkey?
    - C→D:
      - Is C a superkey? No. Not in BCNF.
      - Is D part of a key? No. Not in 3NF.

Checking Normal Forms

- **Example 2.1**
  - ***R***=(A,B,C,D), ***F***={AB→C, AB→D, C→A, D→B}.
  - Identify the best normal form that ***R*** satisfies.

- **Solution**
  - Identify all candidate keys:
    - A, B, C, D: *closure*(A)=A, *closure*(B)=B, *closure*(C)=AC, *closure*(D)=BD. A, B, C, D are not keys.
    - AB: AB→C, AB→D, *closure*(AB)=ABCD. AB is a candidate key.
    - AD, BC, CD are other candidate keys.
  - Checking every non-trivial FD:
    - AB→C, AB→D:
      - Is AB a superkey?
    - C→A:
      - Is C a superkey? No. Not in BCNF.
      - Is A part of a key?
    - D→B:
      - Is B part of a key? Yes. In 3NF.

Decomposition into Normal Forms

- **Problem**
  - For a relation ***R*** and a set of functional dependencies ***F***, decompose ***R*** into a set of BCNF/3NF relations.
- **Requirements**
  - For BCNF decomposition, we require it to be lossless-join.
  - For 3NF decomposition, we require it to be both lossless-join and dependency-preserving.
- **Algorithm**
  - Decomposition into BCNF:
    - For every FD X→Y in ***F*** that violates the BCNF: decompose into (X,Y) and ***R***-Y.
  - Decomposition into 3NF:
    - Find the minimal cover of ***F*** by making every FD X→Y in it:
      - Only a single attribute on the right of the arrow.
      - Eliminate the redundancy on the left of the arrow.
      - Eliminate the redundancy of the FDs.
    - For every FD X→Y1, …, X→Yn in the minimal cover: create a relation (X,Y1,…,Yn).
    - If none of the keys of ***R*** appear in any of these relations, create a relation for one of the keys.

Decomposition into Normal Forms

- **Example 1.2**
  - ***R***=(A,B,C,D), ***F***={B→C, C→D, C→A}.
  - Decompose ***R*** into a set of BCNF/3NF relations.

- **Solution**
  - BCNF:
    - B is the only key for ***R***.
    - C→D violates BCNF.
    - Decompose into: (A,B,C) and (C,D).
    - C→A in (A,B,C) still violates BCNF.
    - Decompose into: (B,C), (C,D) and (C,A).
    - Any other alternatives?
    - (B,C) and (C,D,A).
    - Is the decomposition lossless-join?
    - Is the decomposition dependency-preserving?
  - What about a 3NF decomposition?

Decomposition into Normal Forms

- **Example 2.2**
  - ***R***=(A,B,C,D), ***F***={AB→C, AB→D, C→A, D→B}.
  - Decompose ***R*** into a set of BCNF relations.

- **Solution**
  - All candidate keys: AB, AD, BC, CD.
  - C→A violates BCNF.
  - Decompose into (B,C,D) and (C,A).
  - D→B violates BCNF in (B,C,D).
  - Decompose into (D,B), (C,D), (C,A).
  - Is the decomposition dependency-preserving?
  - Any other alternatives?
    - D→B violates BCNF: Decompose into (A,C,D) and (D,B).
    - C→A violates BCNF in (A,C,D): Decompose into (C,D), (C,A), (D,B).
  - Could there be different BCNF decompositions?

Decomposition into Normal Forms

- **Example 3**
  - ***R***=(A,B,C,D,E,F), ***F***={A→BCD, BC→DE, B→D, D→A}. Decompose ***R*** into a set of 3NF relations.

- **Solution**
  - Find the minimal cover:
    - Single attributes: A→B, A→C, A→D, BC→D, BC→E, B→D, D→A.
    - Minimize left side:
      - BC→D: *closure*(B)={ABCDE}, C is redundant.
      - BC→E: *closure*(B)={ABCDE}, C is redundant.
      - Results: A→B, A→C, A→D, B→D, B→E, D→A.
    - Eliminate FD redundancy:
      - A→B: *closure**(A)={ACD}, not redundant.
      - A→C: *closure**(A)={ABD}, not redundant.
      - A→D: *closure**(A)={ABCDE}, redundant.
      - B→D: *closure**(B)={BE}, not redundant.
      - B→E: *closure**(B)={ABCD}, not redundant.
      - D→A: *closure**(D)={D}, not redundant.

Decomposition into Normal Forms

- **Example 3**
  - ***R***=(A,B,C,D,E,F), ***F***={A→BCD, BC→DE, B→D, D→A}. Decompose ***R*** into a set of 3NF relations.

- **Solution**
  - The minimal cover: A→B, A→C, B→D, B→E, D→A.
  - Find all the candidate keys:
    - F must be part of the key.
    - *closure*(A)={ABCDE}, *closure*(B)={ABCDE}, *closure*(D)={ABCDE}.
    - C and E alone or together can't determine any other attributes.
    - All the candidate keys: AF, BF, DF.
  - The 3NF decomposition:
    - (A,B,C).
    - (B,D,E).
    - (D,A).
    - (A,F).
  - Is the decomposition lossless-join?
  - Is the decomposition dependency-preserving?

Review

- **Review Session**
  - Sunday Dec. 8th, 6-8pm. Phelps 3526.
  - Discuss problems in past exams. Q&A.
  - Return HW 1-4.
- **TA Evaluation**
  - Your inputs are important for improving my teaching skills and quality!
  - Written comments are highly appreciated!
    - Please use pen for written comments.
    - If you don't have written comments, please don't write ANYTHING (including name) on the written comment sheet.
- **Q&A**