Database Management Systems, Aug–Dec 2023

Solution sheet, 29 September 2023

Problem 1 Consider the following functional dependencies over the attributes (A, B, C, D, E).

$$A \rightarrow BC$$
$$CD \rightarrow E$$
$$B \rightarrow D$$
$$E \rightarrow A$$

Compute the attribute closure X^+ for each attribute $X \in \{A, B, C, D, E\}$.

Solution

- $A+ = \{A\}$

  Using $A \rightarrow BC$, expand A^+ to $\{A, B, C\}$

  Using $B \rightarrow D$, expand A^+ to $\{A, B, C, D\}$

  Using $CD \rightarrow E$, expand A^+ to $\{A, B, C, D, E\}$
- $B^+ = \{B\}$

  Using $B \rightarrow D$, expand B^+ to $\{B, D\}$

  No further dependencies have LHS in B^+, so stop.
- $C^+ = \{C\}$

  No dependency has LHS C, so stop.
- $D^+ = \{D\}$

  No dependency has LHS D, so stop.
- $E^+ = \{E\}$

  Using $E \rightarrow A$, expand E^+ to $\{A, E\}$

  (We know $A^+ = \{A, B, C, D, E\}$ so we can directly conclude $E^+ = \{A, B, C, D, E\}$.)

  Using $A \rightarrow BC$, expand E^+ to $\{A, B, C, E\}$

  Using $B \rightarrow D$, expand E^+ to $\{A, B, C, D, E\}$

Problem 2 Consider the following tables for an online book seller.

```
CREATE TABLE Books (
  isbn CHAR(10),
  title CHAR(80),
  author CHAR(80),
  qty_in_stock INTEGER,
  price REAL,
  year_published INTEGER,
)

CREATE TABLE Customers (
  cid INTEGER,
  cname CHAR(80),
  address CHAR(200)
)
```

```
CREATE TABLE Orders (
   ordernum INTEGER,
   isbn CHAR(10),
   cid INTEGER,
   cardnum CHAR(16),
   qty INTEGER,
   order_date DATE,
   ship_date DATE
)
```

We have the following assumptions about these tables.

- `isbn` is a unique identifier for each book published.
- A book has only one title but may have multiple authors.
- `cid` is a unique customer id for each customer.
- `ordernum` is a unique identifier for each order.
  - An order is placed by a single customer `cid`, paid by a single card `cardnum` on a single order date `order_date`.
  - An order may consist of several books (distinct `isbn`) each with its own order quantity (`qty`).
  - Each book is shipped (`ship_date`) as soon as the quantity required is ready.
  - Hence each order is split in several rows, one per `isbn` orderedn.

Questions:

1. Enumerate the functional dependencies that you can infer from this information.
2. For each table, determine if it in BCNF or 3NF. If not, suggest a decomposition and check if the decomposition is dependency preserving.

Solution

1. Functional dependencies
   - `isbn` → `title`, `qty_in_stock`, `price`, `year_published`
   - `cid` → `cname`, `caddress`
   - `ordernum` → `cid`, `cardnum`, `order_date`
   - `ordernum`, `isbn` → `qty`, `ship_date`
2. Normal forms
   - `isbn` is not a key for `Books` (we can have multiple authors for a book). Since we have the dependency `isbn` → `title`, `qty_in_stock`, `price`, `year_published`, `Books` is not in BCNF. `Books` is also not in 3NF, since the only candidate key is (`isbn`,`author`).

     Split `Books` as (`isbn,`author) `and (`isbn,title,qty_in_stock,price,year_published‘) to get a decomposition in BCNF.

     The only dependency that applies can be checked locally in the second table, so the decomposition is dependency preserving.
   - `Customer` is in BCNF since `cid` is a key for the dependency `cid` → `cname`, `caddress`
   - `Orders` is neither in BCNF nor in 3NF.

     Split as (`ordernum`,`cid`,`cardnum`,`order_date`) and (`ordernum`,`isbn`,`qty`,`ship_date`).

     In the first relation, `ordernum` is a key, so it is in BCNF with respect to the dependency `ordernum` → `cid`, `cardnum`, `order_date`.

     In the second relation (`ordernum`,`isbn`) is a key, so it is in BCNF with respect to the dependency `ordernum`, `isbn` → `qty`, `ship_date`

     The two dependencies that apply can be checked locally in the two tables, so the decomposition is dependency preserving.

Problem 3 Suppose we have dependencies $\{A \to BC, B \to CA, C \to AB\}$ on attributes (A, B, C).

Questions:

1. Show that C is extraneous on the right hand side of the first dependency.
2. If we replace the first dependency by $A \to C$, show that both A and B are (separately) extraneous in $C \to AB$.
3. If we replace $C \to AB$ by $C \to A$, so that the dependencies are $\{A \to B, B \to AC, C \to A\}$, show that A is extraneous in $B \to AC$.
4. If we replace $C \to AB$ by $C \to B$, so that the dependencies are $\{A \to B, B \to AC, C \to B\}$, show that neither A nor C are extraneous in $B \to AC$.

Solution

1. To show that C is extraneous in $A \to BC$, we need to check if $A \to BC$ can be derived from $\{A \to B, B \to CA, C \to AB\}$. Compute A^+ with respect to the new set of dependencies.

   $A^+ = \{A\}$

   Using $A \to B$, expand A^+ to $\{A, B\}$

   Using $B \to CA$, expand A^+ to $\{A, B, C\}$

   From this, we deduce the dependency $A \to BC$.

2. Consider the dependencies $\{A \to B, B \to CA, C \to AB\}$.

   - To show that A is extraneous in $C \to AB$, we need to check that we can derive $C \to AB$ from $\{A \to B, B \to CA, C \to B\}$. Compute C^+ with respect to the new sett of dependencies.

     $C^+ = \{C\}$

     Using $C \to B$, expand C^+ to $\{B, C\}$

     Using $B \to CA$, expand C^+ to $\{A, B, C\}$

     From this, we deduce the dependency $C \to AB$.

   - To show that B is extraneous in $C \to AB$, we need to check that we can derive $C \to AB$ from $\{A \to B, B \to CA, C \to A\}$. Compute C^+ with respect to the new sett of dependencies.

     $C^+ = \{C\}$

     Using $C \to A$, expand C^+ to $\{A, C\}$

     Using $A \to B$, expand C^+ to $\{A, B, C\}$

     From this, we deduce the dependency $C \to AB$.

3. Consider the dependencies $\{A \to B, B \to AC, C \to A\}$. We wish to show that A is extraneous in $B \to AC$.

   Check that we can derive $B \to AC$ from $\{A \to B, B \to C, C \to A\}$. Compute B^+ with respect to the new sett of dependencies.

   $B^+ = \{B\}$

   Using $B \to C$, expand B^+ to $\{B, C\}$

   Using $C \to A$, expand B^+ to $\{A, B, C\}$

   From this, we deduce the dependency $B \to AC$..

4. Consider the dependencies $\{A \to B, B \to AC, C \to B\}$. We wish to show that neither A not C is extraneous in $B \to AC$.

- To show that A is not extraneous, check if we can derive $B \rightarrow AC$ from $\{A \rightarrow B, B \rightarrow C, C \rightarrow B\}$. Compute B^+ with respect to the new sett of dependencies.

  $B^+ = \{B\}$

  Using $B \rightarrow C$, expand B^+ to $\{B, C\}$

  The only other dependency whose LHS is in B^+ is $B \rightarrow C$ which adds nothing to B^+, so we stop with $B^+ = \{B, C\}$

  Thus we do not have $B \rightarrow A$, and hence $B \rightarrow AC$ is not derivable.

- To show that C is not extraneous, check if we can derive $B \rightarrow AC$ from $\{A \rightarrow B, B \rightarrow A, C \rightarrow B\}$. Compute B^+ with respect to the new sett of dependencies.

  $B^+ = \{B\}$

  Using $B \rightarrow A$, expand B^+ to $\{A, B\}$

  The only other dependency whose LHS is in B^+ is $A \rightarrow B$ which adds nothing to B^+, so we stop with $B^+ = \{A, B\}$

  Thus we do not have $B \rightarrow C$, and hence $B \rightarrow AC$ is not derivable.
