

CS 186 - Homework 2 Solutions

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2.1 Recovery

- 1) a) Pages $P1, P2$ are dirty and written to disk.
b) No transactions are active. $T1$ has committed and $T2$ has aborted.
- 2) a) $T2$ requires exclusive locks on $P2$ to update it.
b) $T2$ can release its $P2$ lock immediately after Timestamp 60 when it finishes undoing its changes.
- 3) We place all active transactions into the undo list. Since there aren't any, we get:
 - undo: \square
 - redo: \square
- 4) Now we place active transactions into undo list and move committed transactions to the redo list
 - undo: $[T4]$
 - redo: $[T3]$
- 5) For $T4$, we consider timestamps $170 \rightarrow 160 \rightarrow 130 \rightarrow 120$.
- 6) For $T3$, we consider timestamps $100 \rightarrow 110 \rightarrow 140 \rightarrow 150$.

2.2 Functional dependencies

- 1) The closure of A is the set $\{A, B, C, D, E, F\}$, or every element.
This is because $A \rightarrow BC$ and so $C \rightarrow D$ and so $CD \rightarrow EF$.
- 2) The minimal cover are the relations are the dependencies:

$$A \rightarrow B, A \rightarrow C, C \rightarrow D, E \rightarrow A, F \rightarrow C, C \rightarrow E, C \rightarrow F$$

To get this, first, we expanded and simplified the dependencies

$$A \rightarrow B, A \rightarrow C, C \rightarrow D, C \rightarrow A, E \rightarrow A, E \rightarrow B, E \rightarrow C, F \rightarrow C, F \rightarrow D, CD \rightarrow B, CD \rightarrow E, CD \rightarrow F$$

Then, we notice that $C \rightarrow D$ so $C \rightarrow CD \rightarrow BEF$. This simplifies the set to

$$A \rightarrow B, A \rightarrow C, C \rightarrow D, C \rightarrow A, E \rightarrow A, E \rightarrow B, E \rightarrow C, F \rightarrow C, F \rightarrow D, \mathbf{C \rightarrow B}, \mathbf{C \rightarrow E}, \mathbf{C \rightarrow F}$$

And finally, we eliminated redundant dependencies:

$$\mathbf{C \rightarrow A : C \rightarrow E \rightarrow A}$$

$$\mathbf{E \rightarrow B : E \rightarrow A \rightarrow B}$$

$$\mathbf{E \rightarrow C : E \rightarrow A \rightarrow C}$$

$$\mathbf{F \rightarrow D : F \rightarrow C \rightarrow D}$$

$$\mathbf{C \rightarrow B : C \rightarrow A \rightarrow B}$$

- 3) The candidate keys are A, C, E, F because each of these attributes implies every other attribute.

2.3 Moar Functional Dependencies

- 1) The closure of $\{A, B\}$ is every attribute: $\{A, B, C, D, E, F\}$.
- 2) The closure of $\{D, E\}$ is every attribute: $\{A, B, C, D, E, F\}$.
- 3) So yes, the closures are the same and $\{A, B\} \cong \{D, E\}$.
- 4) $\{D, E\} \rightarrow C$ is redundant because $\{D, E\} \rightarrow AB \rightarrow C$, so it is a transitive dependency.
- 5) The D in $AD \rightarrow F$ is redundant because $A \rightarrow D$, so $A \rightarrow AD$, and thus $A \rightarrow F$.
- 6) The minimal cover is everything except for the two redundancies above:

$$AB \rightarrow C, A \rightarrow D, B \rightarrow E, DE \rightarrow A, DE \rightarrow B, A \rightarrow F$$

- 7) The candidate keys are $\{AB, DE, BD, AE\}$.
- 8) R is not in BCNF because of the relations $A \rightarrow D$, $B \rightarrow E$, and $AD \rightarrow F$, where A and B are not a superkeys. From the first one, we decompose to get AD and the rest. From the second we decompose to get BE and the rest, $ABCF$. From the last one, which is equivalent to $A \rightarrow F$, we decompose $ABCF$ into AF and ABC . This yields four relations:

$$R_1 = \{[A, B, C]\}, R_2 = \{[A, D]\}, R_3 = \{[B, E]\}, R_4 = \{[A, F]\}$$

- 9) R is not in 3NF because of the FD $AD \rightarrow F$, where AD is not a proper subset of either candidate keys AB and DE . We fix that by using the loss-less join decomposition above (the BCNF partition). Since any BCNF relations are also 3NF relations, the BCNF partition above satisfies 3NF.

2.4 Decomposition in 3NF and BCNF

1) R1 The minimal cover is:

$$A \rightarrow B, A \rightarrow E, A \rightarrow F, B \rightarrow C, B \rightarrow D, CD \rightarrow A$$

And the candidate keys are A, B, CD .

R2 The minimal cover is:

$$DE \rightarrow A, DE \rightarrow B, B \rightarrow C, C \rightarrow D, C \rightarrow E, C \rightarrow F$$

And the candidate keys are B, C, DE .

R3 The minimal cover is:

$$E \rightarrow A, E \rightarrow C, FD \rightarrow E, B \rightarrow D, B \rightarrow F, C \rightarrow B$$

And the candidate keys are B, C, E, DF .

R4 The minimal cover is:

$$A \rightarrow B, B \rightarrow C, C \rightarrow D, D \rightarrow E, D \rightarrow F, D \rightarrow A$$

And the candidate keys are A, B, C, D .

- 2) R1 $R1$ already satisfies BCNF. Thus, the original relational schema $R_1 = \{[\underline{A}, B, C, D, E, F]\}$ is a lossless-join BCNF decomposition as well as a dependency-preserving 3NF decomposition. A key is A .
- R2 $R2$ already satisfies BCNF. Thus, the original relational schema $R_2 = \{[A, \underline{B}, C, D, E, F]\}$ is a lossless-join BCNF decomposition as well as a dependency-preserving 3NF decomposition. A key is B .
- R3 $R3$ already satisfies BCNF. Thus, the original relational schema $R_3 = \{[A, \underline{B}, C, D, E, F]\}$ is a lossless-join BCNF decomposition as well as a dependency-preserving 3NF decomposition. A key is B .
- R4 $R4$ already satisfies BCNF. Thus, the original relational schema $R_4 = \{[\underline{A}, B, C, D, E, F]\}$ is a lossless-join BCNF decomposition as well as a dependency-preserving 3NF decomposition. A key is A .
- 3) a) Decomposition $R_{11} = \{[A, B, C, D, E, F]\}$ is a lossless join, dependency-preserving, 3NF, and BCNF.
- b) Decomposition $R_{11} = \{[A, B, C, D, E]\}$, $R_{12} = \{[C, D, F]\}$ is a lossless join, dependency-preserving, 3NF, and BCNF.

- c) Decomposition $R_{11} = \{[A, B, E]\}$, $R_{12} = \{[B, C, D, F]\}$ is a lossless join, dependency-preserving, 3NF, and BCNF. *Note: it appears that many people think this decomposition is not dependency-preserving, and I would intuitively agree. However, the definition of dependency preserving states that $F^+ = (F_x \cup F_y)^+$. Here, since F_X is the projection of the CLOSURE of F onto X , and since A, B, CD are candidate keys, we get everything, including $B \rightarrow A$ in R_{11} . Thus, we satisfy dependencies like $CD \rightarrow A$ by $CD \rightarrow B \rightarrow A$.
- d) Decomposition $R_{31} = \{[B, C, E]\}$, $R_{32} = \{[A, B, D, E, F]\}$ is a lossless join, dependency-preserving, 3NF, and BCNF.
- e) Decomposition $R_{31} = \{[A, B, C, D, E, F]\}$ is a lossless join, dependency-preserving, 3NF, and BCNF.
- f) Decomposition $R_{31} = \{[A, B, C, E]\}$, $R_{32} = \{[B, D, F]\}$ is a lossless join, dependency-preserving, 3NF, and BCNF.