

COMP2400/6240 - Relational Databases

Assignment on Database Theory

Assignment on Database Theory (Solutions)

Due date: 23:59, 8 October 2019

This assignment will be marked out of 15. It will count for 15% of the final grade. Marks are assigned for the process of finding a solution, not only for the result. Hence, include all essential ideas and steps that are necessary to derive a solution.

Instructions:

- This assignment should be done by a group of two students or individually. COMP2400 students can only be paired with other COMP2400 students. COMP6240 students can only be paired with other COMP6240 students.
- You must submit two files on Wattle before the due date:
 1. “u1234567-u7654321-ass2.pdf” (replace u1234567 and u7654321 with your UID and your group partner’s UID, respectively). Make sure you only upload the PDF file, not a Word or text file. **This PDF file should contain a JPEG figure as the EER diagram exported from TerraER.**
 2. “u1234567-u7654321-ass2.xml” (replace u1234567 and u7654321 with your UID and your group partner’s UID, respectively). This is the XML file that corresponds to the EER diagram drawn by TerraER.
- For each group, you only need to submit a single copy of your assignment on Wattle under either your UID or your partner’s UID.
- Late submission is **not** considered. If you have submitted at the time of the deadline, please do not submit a second copy. If you are in a situation beyond your control, please contact ANU’s special consideration committee for consideration (https://eduassistpro.github.io/registration/assessments-exams/special-assessment-consideration).
- Plagiarism will attract academic penalties in accordance with the ANU’s policy. If you are expected to be able to explain and defend any submitted assessment item, you may be required to initiate an additional interview about any submitted assessment item for any student. If there is a significant discrepancy between the two forms of assessment, it will be automatically treated as a case of suspected academic misconduct.

Question 1

4 Marks

ACTRides is a car rental company which has been founded recently in Canberra. It currently has 5 branches opened in Acton, Belconnen, Dickson, Braddon and Woden, respectively. ACTRides is planning to expand to areas such as Tuggeranong and Manuka in the future. A branch has a unique address but may have multiple telephone numbers. Each rental car must be associated with exactly one ACTRides branch. A rental car can be identified by its registration number and has the information about the model and the production year. Each employee working at ACTRides has a tax file number (TFN), a name and an address. ACTRides employees consist of managers, mechanics and customer service representatives. Every employee must work at exactly one branch. A customer of ACTRides should provide their drivers license number, their name and a contact number. A customer can rent a car from an ACTRides branch and details about the rental such as the rental period and price should be recorded. If a customer is not satisfied with the rental service provided, this customer may submit a complaint to a customer service representative and thus a distinct reference number and detailed description of the complaint should be recorded. The manager of a branch will handle all the complaints with respect to this branch and has an urgent contact number in case of emergency. Mechanics working at a branch inspect the cars associated with the branch and record the condition and inspection date. A car must be inspected at least two times per year. Each mechanic has a skill level and might have another mechanic as the supervisor. The supervisor must have a higher skill level compared to the mechanics supervised by this supervisor.

Your task is to design an Enhanced Entity Relationship (EER) diagram for the above database, which should include entities, relationships, attributes and constraints wherever appropriate (you can make more assumptions if necessary).

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You also need to identify the requirements that cannot be captured in an EER-diagram.

Requirements that cannot be captured in the EER-diagram:

- A car must be inspected at least two times per year.
- The supervisor must have a higher skill level compared to the mechanics supervised by this supervisor.

Question 2

4 Marks

Consider the relation schema $R=\{A, B, C, D, E\}$ and the following set Σ of FDs:

- $A \rightarrow B$
- $AB \rightarrow DE$
- $C \rightarrow B$
- $BE \rightarrow AC$

- 2.1 What are the candidate keys of R? Justify your answer (i.e., include the main steps used for finding the candidate keys). (2 Mark)

Consider 1 attribute at a time. Only the closure of A will give you all the attributes in R:

$$\{A\}^+ = \{AB\}^+ = \{ABDE\}^+ = \{ABCDE\}^+ \checkmark$$

Hence $\{A\}$ is a candidate key.

Consider combinations of 2 attributes which do not contain A. Only the closure of BE and CE will give you all the attributes in R:

$$\{BE\}^+ = \{BEAC\}^+ = \{ABCDE\}^+ \checkmark$$

$$\{CE\}^+ = \{CE\}^+ = \{BCE\}^+ = \{ABCDE\}^+ \checkmark$$

Hence $\{BE\}$ and $\{CE\}$ are also candidate keys.

There is only one combination of 3 attributes $\{BCD\}$ that does not contain A, BE or CE, but $\{BCD\}$ is not a superkey because $\{BCD\}^+ = \{BCD\}$.

In summary, $\{A\}$, $\{BE\}$ and $\{CE\}$ are three candidate keys of R.

- 2.2 Find a minimal cover of Σ . Justify your answer (i.e., include the main steps used for finding a minimal cover). (2 Mark)

To find the minimal cover we first ensure that all the FDs determine only one attribute:

$$\Sigma' = \{A \rightarrow B, C \rightarrow B, A \rightarrow D, A \rightarrow E, BE \rightarrow A, BE \rightarrow C\}$$

Now check for redundancy at Σ' :

Replace $AB \rightarrow D$ with $A \rightarrow D$? $D \in \{A\}^+$ under $\Sigma' - \{AB \rightarrow D\}$? No. Replace $AB \rightarrow E$ with $A \rightarrow E$? $E \in \{A\}^+$ under $\Sigma' - \{AB \rightarrow E\}$? No. Replace $BE \rightarrow C$ with $E \rightarrow C$? $C \in \{BE\}^+$ under $\Sigma' - \{BE \rightarrow C\}$? No. Replace $BE \rightarrow A$ with $B \rightarrow A$? $A \in \{BE\}^+$ under $\Sigma' - \{BE \rightarrow A\}$? No. Replace $BE \rightarrow A$ with $E \rightarrow A$? $A \in \{BE\}^+$ under $\Sigma' - \{BE \rightarrow A\}$? No.

Replace $AB \rightarrow E$ with $A \rightarrow E$? $E \in \{A\}^+$ under $\Sigma' - \{AB \rightarrow E\}$? No.

ith $A \rightarrow E$

Replace $BE \rightarrow C$ with $E \rightarrow C$? $C \in \{BE\}^+$ under $\Sigma' - \{BE \rightarrow C\}$? No.

Replace $BE \rightarrow C$ with $E \rightarrow C$? $C \in \{BE\}^+$ under $\Sigma' - \{BE \rightarrow C\}$? No.

Replace $BE \rightarrow A$ with $B \rightarrow A$? $A \in \{BE\}^+$ under $\Sigma' - \{BE \rightarrow A\}$? No. \times No replacement

Replace $BE \rightarrow A$ with $E \rightarrow A$? $A \in \{BE\}^+$ under $\Sigma' - \{BE \rightarrow A\}$? No. \times No replacement Now we get:

$$\Sigma' = \{A \rightarrow B, C \rightarrow B, A \rightarrow D, A \rightarrow E, BE \rightarrow A, BE \rightarrow C\}$$

Lastly check if any FDs are redundant:

$A \rightarrow B$? $B \in \{A\}^+$ under $\Sigma' - \{A \rightarrow B\}$? $\{A\}^+ = \{ADE\}^+ = \{ADE\}$ \times Keep $A \rightarrow B$

$C \rightarrow B$? $B \in \{C\}^+$ under $\Sigma' - \{C \rightarrow B\}$? $\{C\}^+ = \{C\}$ \times Keep $C \rightarrow B$

$A \rightarrow D$? $D \in \{A\}^+$ under $\Sigma' - \{A \rightarrow D\}$? $\{A\}^+ = \{ABE\}^+ = \{ABCE\}$ \times Keep $A \rightarrow D$

$A \rightarrow E$? $E \in \{A\}^+$ under $\Sigma' - \{A \rightarrow E\}$? $\{A\}^+ = \{ABD\}^+ = \{ABD\}$ \times Keep $A \rightarrow E$

$BE \rightarrow A$? $A \in \{BE\}^+$ under $\Sigma' - \{BE \rightarrow A\}$? $\{BE\}^+ = \{BCE\}^+ = \{BCE\}$ \times Keep $BE \rightarrow A$

$BE \rightarrow C$? $C \in \{BE\}^+$ under $\Sigma' - \{BE \rightarrow C\}$? $\{BE\}^+ = \{ABE\}^+ = \{ABDE\}$ \times Keep $BE \rightarrow C$

Therefore our minimal cover is (in both minimal Σ_M and canonical Σ_C form):

$$\Sigma_M = \{A \rightarrow B, C \rightarrow B, A \rightarrow D, A \rightarrow E, BE \rightarrow A, BE \rightarrow C\}$$

$$\Sigma_C = \{A \rightarrow BDE, C \rightarrow B, BE \rightarrow AC\}$$

Question 3**2 Marks**

Consider the relation schema $\text{APPOINTMENT} = \{\text{Customer, Date, Staff, Room, Branch}\}$ and the following set Σ of FDs:

- $\text{Branch, Date, Staff} \rightarrow \text{Room}$
- $\text{Customer, Date} \rightarrow \text{Staff}$
- $\text{Branch, Date, Room} \rightarrow \text{Staff}$
- $\text{Branch, Customer, Date} \rightarrow \text{Room}$

Is the above relation schema APPOINTMENT in BCNF? If not, identify a BCNF decomposition for APPOINTMENT . You need to include the main steps used for identifying the BCNF decomposition. Check if this BCNF decomposition is dependency preserving. (2 Mark)

We alias the attributes to the first letter of their names for brevity, and order alphabetically.

To check whether APPOINTMENT in BCNF, we need check whether all the FDs meet the BCNF requirement (that for all $X \rightarrow Y$ in APPOINTMENT , X is a super key). We check the closure of the determining side of each FD to see if all the attributes of APPOINTMENT are included:

$$\{BDS\}^+ = \{BDRS\} \quad \times$$

$$\{CD\}^+ = \{CDS\} \quad \times$$

$$\{BDR\}^+ = \{BDRS\}$$

$$\{BCD\}^+ = \{BCDR\}$$

Hence, APPOINTMENT is not in BCNF.

Now we select FDs that violate BCNF requirements and use them to decompose APPOINTMENT iteratively.

We first select $BDS \rightarrow R$ and produce the following relations and associated FDs.

$$R_A = \{B, C, D, S\} \quad \Sigma_{R_A} = \{CD \rightarrow S\}$$

$$R_B = \{B, D, R, S\} \quad \Sigma_{R_B} = \{BDR \rightarrow S, BDS \rightarrow R\}$$

Note that $BCD \rightarrow R$ is lost.

Note that R_B (with respect to $\Sigma_{R_B} = \{BDR \rightarrow S, BDS \rightarrow R\}$) is now in BCNF because both BDR and BDS are superkeys. However, R_A (with respect to $\Sigma_{R_A} = \{CD \rightarrow S\}$) is not in BCNF because CD is not a superkey in R_A . Thus we select $CD \rightarrow S$ and produce the following decomposition of R_A into R_{A1} and R_{A2} .

$$R_{A1} = \{B, C, D\} \quad \Sigma_{R_{A1}} = \emptyset$$

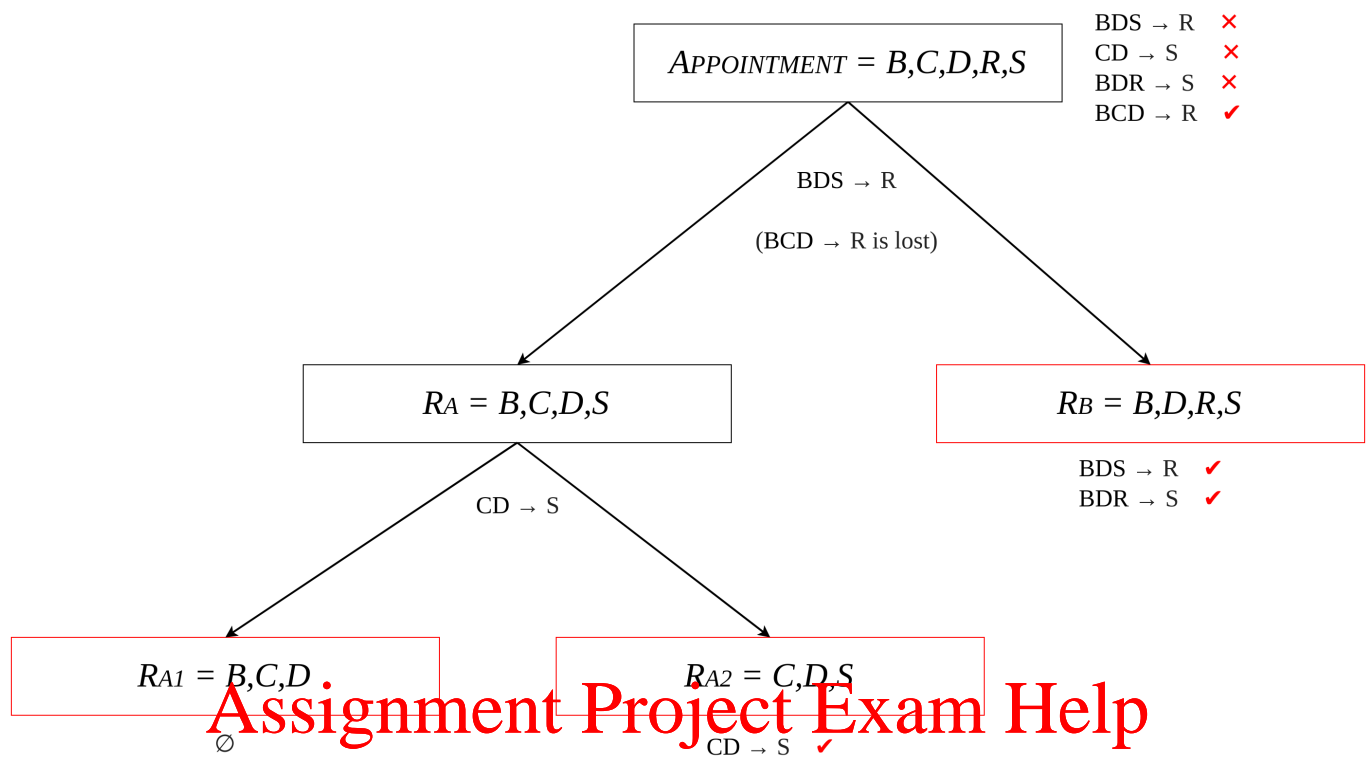
$$R_{A2} = \{C, D, S\} \quad \Sigma_{R_{A2}} = \{CD \rightarrow S\}$$

$$R_B = \{B, D, R, S\} \quad \Sigma_{R_B} = \{BDR \rightarrow S, BDS \rightarrow R\}$$

Now R_{A1} , R_{A2} and R_B are in BCNF and thus $S = \{R_{A1}, R_{A2}, R_B\}$ is the BCNF decomposition of APPOINTMENT .

To verify whether S is dependency-preserving, we need to check whether:

$$\left(\bigcup_{R \in S} \Sigma_R \right) \stackrel{?}{\rightarrow} \{BCD \rightarrow R\}$$



So we check $\{BCD\}^+$ under R_B . Since we can determine R from BCD , this FD can be recovered.

NOTE: There may be different ways for BCNF decomposition depending on the one such possible decomposition.

Question 4

4 Marks

Consider the following database schema of a booking system.

CUSTOMER = {CustomerID, Name, Phone}
PK: {CustomerID}

EMPLOYEE = {EmployeeID, Name}
PK: {EmployeeID}

HOTEL = {HotelNo, RoomNo, Phone}
PK: {HotelNo, RoomNo}

BOOKING = {CID, EID, HNo, RNo, Date, Price}
PK: {CID, EID, HNo, RNo, Date}

FK: $[CID] \subseteq \text{CUSTOMER}[\text{CustomerID}]$, $[EID] \subseteq \text{EMPLOYEE}[\text{EmployeeID}]$,
 $[HNo, RNo] \subseteq \text{HOTEL}[\text{HotelNo}, \text{RoomNo}]$

4.1 Answer the following question using relational algebra expressions. You are encouraged to use relational algebra expressions to represent intermediate results if needed.

[a] Find all the employees who have never helped any customer to book rooms in a hotel named "WestWorld" (i.e., $HNo = \text{'WestWorld'}$). List their EmployeeIDs. (1 Mark)

$\pi_{\text{EmployeeID}}(\text{EMPLOYEE}) - \pi_{\text{EID}}(\sigma_{HNo = \text{'WestWorld'}}(\text{BOOKING}))$

[b] Find all the customers who have booked exactly one hotel room on 10-01-2019. List their CustomerIDs and names. (1 Mark)

$$C_1 = \pi_{CustomerID, Name}(\pi_{CID}(\sigma_{Date='10-01-2019'}(BOOKING)) \bowtie_{CID=CustomerID} CUSTOMER)$$

$$S_2 = \rho_{B1}(BOOKING) \bowtie_{(B1.CID=B2.CID) \wedge (B1.Date=B2.Date) \wedge ((B1.HNo \neq B2.HNo) \vee (B1.RNo \neq B2.RNo))} \rho_{B2}(BOOKING)$$

$$C_2 = \pi_{CustomerID, Name}(CUSTOMER \bowtie_{(CustomerID=B1.CID) \wedge (B1.Date='10-01-2019')} S_2)$$

$$Result = C_1 - C_2$$

4.2 Optimize the following relational algebra query (Your marks will depend on how well you present the key ideas of query optimization in your answer). In addition to this, draw the query trees correspond to queries before and after your optimisation.

$$\pi_{CustomerID, Name, Date, HNo}(\sigma_{(CID=CustomerID) \wedge (HNo=HotelNo) \wedge (RNo=RoomNo) \wedge (Price>200)}(BOOKING \times CUSTOMER \times HOTEL))$$
 (2 Mark)

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Figure 1: Final query tree after optimising.

Question 5

1 Marks

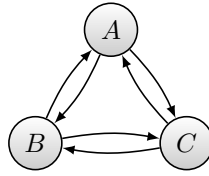
Consider the relation schema $R=\{A, B, C\}$ and the following set Σ of FDs:

- $A \rightarrow B$
- $A \rightarrow C$
- $B \rightarrow A$
- $B \rightarrow C$
- $C \rightarrow A$
- $C \rightarrow B$

How many different minimal covers can be derived from Σ ? List all the minimal covers that you can derive from Σ . (1 Mark)

All FDs determine only one attribute and there are no redundant attributes on the determining side.

Now we can visualise the FDs in a graph as given below.



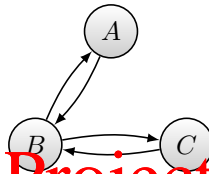
We can remove different combinations of redundant FDs and obtain five minimal covers as shown below.

Minimal cover 1:

Considering $A \rightarrow B$ and $B \rightarrow C$, we can remove $A \rightarrow C$ as it is redundant.

Considering $C \rightarrow B$ and $B \rightarrow A$, we can remove $C \rightarrow A$ as it is redundant.

$$\Sigma_{M_1} = \{A \rightarrow B, B \rightarrow C, C \rightarrow B, B \rightarrow A\}$$



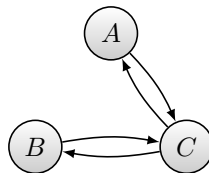
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Minimal cover 2:

Considering $A \rightarrow C$ and

Considering $B \rightarrow C$ and $C \rightarrow A$, we can remove $B \rightarrow A$ as

$$\Sigma_{M_2} = \{A \rightarrow C, C \rightarrow B, B \rightarrow C, C \rightarrow A\}$$

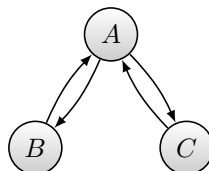


Minimal cover 3:

Considering $C \rightarrow A$ and $A \rightarrow B$, we can remove $C \rightarrow B$ as it is redundant.

Considering $B \rightarrow A$ and $A \rightarrow C$, we can remove $B \rightarrow C$ as it is redundant.

$$\Sigma_{M_3} = \{C \rightarrow A, A \rightarrow B, B \rightarrow A, A \rightarrow C\}$$



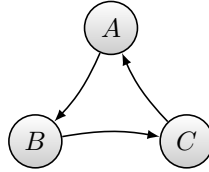
Minimal cover 4:

Considering $A \rightarrow B$ and $B \rightarrow C$, we can remove $A \rightarrow C$ as it is redundant.

Considering $C \rightarrow A$ and $A \rightarrow B$, we can remove $C \rightarrow B$ as it is redundant.

Considering $B \rightarrow C$ and $C \rightarrow A$, we can remove $B \rightarrow A$ as it is redundant.

$$\Sigma_{M_4} = \{A \rightarrow B, B \rightarrow C, C \rightarrow A\}$$



Minimal cover 5:

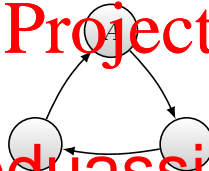
Considering $C \rightarrow B$ and $B \rightarrow A$, we can remove $C \rightarrow A$ as it is redundant.

Considering $A \rightarrow C$ and $C \rightarrow B$, we can remove $A \rightarrow B$ as it is redundant.

Considering $B \rightarrow A$ and $A \rightarrow C$, we can remove $B \rightarrow C$ as it is redundant.

$$\Sigma_{M_5} = \{A \rightarrow C, C \rightarrow B, B \rightarrow A\}$$

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