

# **Concordia University Department of Computer Science and Software Engineering**

SOEN 331 Section S: Formal Methods  
for Software Engineering

## **Assignment 1**

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# Contents

# 1 Problem 1: Predicate Logic 1 (10 pts)

## 1.1 Description:

In the domain of all people in the room, consider the predicate  $received\_request(a, b)$  that is interpreted as

*"[person] a has received a request from [person] b to connect on some social platform"*

1. How are the following two expressions translated into plain English? Are the two expressions logically equivalent?

- $\forall a \exists b \text{ received\_request}(a, b)$ .
- $\exists b \forall a \text{ received\_request}(a, b)$ .

Solution:

The first statement  $\forall a \exists b \text{ received\_request}(a, b)$ . reads that every person a has received a request from one person b.

The second statement  $\exists b \forall a \text{ received\_request}(a, b)$ . reads that there exists a person b which has a received a request from all people a.

In terms of logical equivalency, we would need to determine if the truth values for both of these statements are the same. For the first statement, while it is possible that every person a has received a request from one person b, it is highly unlikely that in the second statement, that one person b has received a request from every person from a. **Hence, both of these statement are NOT logically equivalent.**

2. Discuss in detail whether we can we claim the following:

$$\forall a \exists b \text{ received\_request}(a, b) \rightarrow \exists b \forall a \text{ received\_request}(a, b).$$

Solution:

The statement  $\forall a \exists b \text{ received\_request}(a, b) \rightarrow \exists b \forall a \text{ received\_request}(a, b)$ . is **FALSE**.

The first predicate states that all the people from a have received a request from each

person b. While this does mean that everyone person a received a request from a person b, it does not necessarily mean that all the a people asked the same b people. Every a person could have received a request from a different b person. Predicate 2, however, states that there exists a person b who has received a request from every person a, which we have proved from the above statement is **FALSE**.

3. Discuss in detail whether we can we claim the following:

$$\exists b \forall a \text{ received\_request}(a, b) \rightarrow \forall a \exists b \text{ received\_request}(a, b).$$

Solution:

The statement  $\exists b \forall a \text{ received\_request}(a, b) \rightarrow \forall a \exists b \text{ received\_request}(a, b)$ . is **TRUE**. The first predicates states that there is exists one person b who has a received a request from every person a. The second predicate states that every person a has received a request from atleast one person b which we see from the first predicate to be true, hence we can claim this statement to be **TRUE**.

4. How are the following two expressions translated into plain English? Are the two expressions logically equivalent?

- $\forall b \exists a \text{ received\_request}(a, b)$ .
- $\exists a \forall b \text{ received\_request}(a, b)$ .

Solution:

The first statement  $\forall b \exists a \text{ received\_request}(a, b)$ . reads that every person b has received a request from one such person a. The second statement  $\exists a \forall b \text{ received\_request}(a, b)$ . states that there exists a person a which has a received from every person b. To make sure that these statements are logically equivalent, we would need to determine if the truth values for these statements are the same. While in the first statement, every person b does receive a request from one person a, we have no way to make sure that every person b get the request from the same person a. If that statement would hold, then we could say that there would exist a person a who receives a request from every person b, but since this is not the case **Both of these statements are NOT logically equivalent**.

## 2 Problem 2: Predicate Logic 2 (10 pts)

### 2.1 Description:

Given the subject "being a person" and the predicate "being bad", consider the list of propositions below:

1. "There are some nice people"
2. "There are no nice people"
3. "Everybody is bad"
4. "Some people are bad"
5. "Everybody is nice"
6. "Some people are not nice"

Associate each of the propositions below to one of the standard forms of categorical propositions.

#### Solution:

We can assume in this case that being a person (or people) would be the subject S, denoted by  $P(x)$  and the being bad would be the predicate P, denoted by  $Q(x)$ . Let:

1. "There are some nice people" = This is of the form some S are not P. Translated to proposition form, this would give us  $\exists x, (P(x) \wedge \neg Q(x))$ , **which is O form.**
2. "There are no nice people" = This is of the form of all S are P. Translated to proposition form, this would give us  $\forall x, (P(x) \rightarrow Q(x))$ , **which is A form.**
3. "Everybody is bad" = This is of the form of no S are P. Translated to proposition form, this would give us  $\forall x, (P(x) \rightarrow \neg Q(x))$ , **which is E form.**
4. "Some people are bad" = This is of the form of some S are P. Translated to proposition form, this would give us  $\exists x, (P(x) \wedge Q(x))$ , **which is I form.**

5. "Everybody is nice" = This is of the form of no S are P. this would give us  $\forall x, (P(x) \rightarrow \neg Q(x))$ , **which is E form**.
6. "Some people are not nice" = This is of the form of some S are P. Translated to proposition form, this would give us  $\exists x, (P(x) \wedge Q(x))$ , **which is I form**.

### 3 Problem 3: Unordered and ordered structures (15 pts)

#### 3.1 Description:

Consider the following two sets:

- $OS = \{MacOS, Linux, BSD, Windows, Unix\}$ , and
- $My\_OS = \{BSD, Unix\}$ .

Answer the following questions:

1. Is the following declaration acceptable:  $My\_OS \mathbb{P} OS$ ? Explain.

Solution:

Since the set  $My\_OS$  contains all the values in  $OS$  set, we can say that this is an acceptable declaration.

2. Is  $\mathbb{P} OS$  a legitimate type? Explain.

Solution:

This is a legitimate type, since  $OS$  can assume any variable from the set  $My\_OS$ .

3. What does the following statement signify?  $My\_OS: OS$ . Is the statement acceptable? Explain.

Solution:

We can interpret this as 'The variable  $My\_OS$  can assume any value which is contained in the set  $OS$ '

4. Is  $MacOS \mathbb{P}OS$ ? Explain.

Solution:

Since  $POS$  is a powerset, and a powerset can only contain a set as its element, **this statement is FALSE**, since *MacOS* is an atomic element and not a set.

5. Is  $OS$  a legitimate type?

Solution:

Since we do not have a restriction on what the type can be, **we can say yes that this is a legitimate type**.

6. Is  $\{\} \in \mathbb{P}OS$ ? Explain.

Solution:

Since this is considered as an empty set, and the powerset contains all the subsets including the empty one, **this statement is TRUE**.

7. Is  $\{Linux, BSD\} \in \mathbb{P}OS$ ? Explain.

Solution:

Since the subset of the set  $\{Linux, BSD\}$  is contained in the powerset  $\mathbb{P}OS$ , **we can say that this statement is TRUE**.

8. Is  $\{\{\}\} \in \mathbb{P}OS$ ?

Solution:

As this is translated as the set of the empty set, which is basically the set of a set. This definition is not contained in a powerset, **this statement is FALSE**.

9. Is  $\{\} \in OS$ ? Explain.

Solution:

Since we are talking about an empty set being part of a non-powerset, the  $OS$  set does not need to contain all the subsets like the powerset, **this statement is FALSE**.

10. If we define variable  $My\_Computer : \mathbb{P}OS$ , is  $\{\}$  a legitimate value for variable  $My\_Computer$ ? Explain.

Solution:

With that statement, we are saying that  $My\_Computer$  is a variable for the type  $\mathbb{POS}$ , and that powerset contains all the subsets of the variable which also includes which also includes the empty set like in this case, **this value is legitimate**.

11. If we stated that  $My\_Computer = \{Windows\}$ , would the statement  $My\_Computer$  make an atomic variable?

Solution:

No it would not since  $\{Windows\}$  is a set.

12. Is  $\{\{BSD, MacOS\}\} \subset \mathbb{POS}$ ? Explain.

Solution:

A set of a set is not defined in the powerset, **hence this statement is FALSE**.

13. Is  $My\_OS \subset \mathbb{POS}$ ? Explain.

Solution:

Since the subset of all the elements of the set  $My\_OS$  are in the powerset, **hence this statement is TRUE**.

14. Is  $\{\{BSD, MacOS\}\} \in \mathbb{POS}$ ?

Solution:

As this is again a set of a set, which is not defined for a powerset, **this statement is FALSE**.

## 4 Problem 4: Relational calculus 1 (15 pts)

### 4.1 Description:

Consider a system that associates active flights to airlines. The requirements of the system are as follows:

- Flights are unique.
- Each flight is associated to a single airline, e.g. AA333 is an American Airlines flight.



- The system can support new flights to be associated to an existing airline, or existing flights to be deleted.
- Airlines can have several active flights at any point in time.

We introduce types *Flight* and *Airline*. The model of the system is captured by variable map, as shown below:

$$\begin{aligned} \text{map} = & \\ & \{ \\ & \quad AAA333 \mapsto \textit{American Airlines}, \\ & \quad AY29 \mapsto \textit{Finnair}, \\ & \quad TS261 \mapsto \textit{Air Transat}, \\ & \quad TS765 \mapsto \textit{Air Transat} \\ & \} \end{aligned}$$

1. Is *map* a binary relation? Explain.

Solution:

2. Is *map* a function? Explain and if Yes, determine the type of the function.

Solution:

3. Define the precondition for operation *add*, that adds a new flight-airline pair.

Solution:

Initially we would need to check if the ordered pair exists in maps. To check this, the domain of map should not contain the airline.

If that doesn't exist, then we can add the new ordered pair. The translated statement for the add would be:

***flight*  $\notin$  *dom map***

**For Questions 4 and 5 assume the presence of the above precondition:**

4. Provide two alternative definitions for the core functionality of operation *add*.

Solution:

To add the operation, we can either do a union or we can do the insertion operator.

The statements needed for those would look like the following:

- $map' = map = \cup \{flight \mapsto airline\}$
- $map' = map = \oplus \{flight \mapsto airline\}$

**For Questions 6 and 7 assume that the above precondition is removed:**

5. What would be the result of calling operation *add* with  $flight? = TS765$ , and  $airline? = American Airlines?$

Solution:

6. What would be the result of calling *add* with

$$\begin{aligned} flight? &= AA333, \\ airline? &= AirCanada, \end{aligned}$$

Solution:

7. Under what conditions, if any, can *set union* serve as a mechanism to successfully add a new record into the database table? What error could possibly occur?

Solution:

8. Provide a definition for the core functionality of operation **delete** that erases a flight from *map*, given the flight number.

Solution:

## 5 Problem 5: Relational calculus 2 (25 pts)

### 5.1 Description:

Consider the following binary relation:

$airplanes : Model \leftrightarrow Manufacturer$

where

$airplanes =$

{  
     $A320 \mapsto Airbus,$   
     $A330 \mapsto Airbus,$   
     $A350 \mapsto Airbus,$   
     $A380 \mapsto Airbus,$   
     $737 \mapsto Boeing,$   
     $747 \mapsto Boeing,$   
     $Superjet100 \mapsto Sukhoi,$   
     $C919 \mapsto Comac,$   
     $Global7500 \mapsto Bombardier,$   
     $Global8000 \mapsto Bombardier,$   
     $E170 \mapsto Embraer,$   
     $E175 \mapsto Embraer$   
}

1. What is the value of the following expression:

$$\{A330, 747\} \triangleleft \text{airplanes}$$

Solution:

This is translated to " *select all the pairs of model whose domain is A330 and 747*".

The result that we get from this is

$$\begin{aligned} \{A330, 747\} \triangleleft \text{airplanes} = & \{ \\ & A330 \mapsto \text{Airbus}, \\ & 747 \mapsto \text{Boeing} \\ & \} \end{aligned}$$

2. What is the value of the following expression:

$$\text{airplanes} \triangleright \{Comac, Embraer\}$$

Solution:

This is translated to " *select all the pairs of manufacturers whose range is Comac and Embraer*". The result that we get from this is

$$\begin{aligned} \text{airplanes} \triangleright \{Comac, Embraer\} = & \{ \\ & C919 \mapsto \text{Comac}, \\ & E170 \mapsto \text{Embraer}, \\ & E175 \mapsto \text{Embraer} \\ & \} \end{aligned}$$

3. What is the value of the following expression:

$$\{A320, A330, A350, E170\} \triangleleft \text{airplanes}$$

Solution:

This is translated to "remove all the pairs of models whose domain is *A320*, *A330*, *A350* and *E170*". The result that we get from this is

$$\begin{aligned} \{A320, A330, A350, E170\} \triangleleft \text{airplanes} = & \{ \\ & A380 \mapsto \text{Airbus}, \\ & 737 \mapsto \text{Boeing}, \\ & 747 \mapsto \text{Boeing}, \\ & \text{Superjet100} \mapsto \text{Sukhoi}, \\ & C919 \mapsto \text{Comac}, \\ & \text{Global7500} \mapsto \text{Bombardier}, \\ & \text{Global8000} \mapsto \text{Bombardier}, \\ & E175 \mapsto \text{Embraer} \\ & \} \end{aligned}$$

This is called domain substraction. While this demonstrated what the effect will be, for the effect to properly take place, we must do  $\text{airplanes}' = \{A320, A330, A350, E170\} \triangleleft \text{airplanes}$

4. What is the value of the following expression:

$$\text{airplanes} \triangleright \{\text{Airbus}, \text{Boeing}\}$$

Solution:

This is translated to "remove all the pairs of models whose range is *Airbus* and *Boeing*". The result that we get from this is

$$\begin{aligned}
airplanes \triangleright \{Airbus, Boeing\} = & \{ \\
& Superjet100 \mapsto Sukhoi, \\
& C919 \mapsto Comac, \\
& Global7500 \mapsto Bombardier, \\
& Global8000 \mapsto Bombardier, \\
& E170 \mapsto Embraer, \\
& E175 \mapsto Embraer \\
& \}
\end{aligned}$$

This is called range subtraction. While this demonstrated what the effect will be, for the effect to properly take place, we must do  $airplanes' = airplanes \triangleright \{Airbus, Boeing\}$

5. What is the value of the following expression:

$$airplanes \oplus \{Su\_80 \mapsto Sukhoi\}$$

Solution:

When the symbol  $\oplus$  is involved, we can either assume we are going to insert or modify in the database

In this case, however, we do not have  $Su\_80$  in the database already, hence this has to be an insertion. For an insertion to properly happen in the DB,

We would need to  $airplane' = airplanes \oplus \{Su\_80 \mapsto Sukhoi\}$ , but for the sake of simplicity for this problem, We would have

$$\begin{aligned}
&airplanes \oplus \{Su\_80 \mapsto Sukhoi\} = \{ \\
&\quad A320 \mapsto Airbus, \\
&\quad A330 \mapsto Airbus, \\
&\quad A350 \mapsto Airbus, \\
&\quad A380 \mapsto Airbus, \\
&\quad 737 \mapsto Boeing, \\
&\quad 747 \mapsto Boeing, \\
&\quad Superjet100 \mapsto Sukhoi, \\
&\quad C919 \mapsto Comac, \\
&\quad Global7500 \mapsto Bombardier, \\
&\quad Global8000 \mapsto Bombardier, \\
&\quad E170 \mapsto Embraer, \\
&\quad E175 \mapsto Embraer, \\
&\quad Su\_80 \mapsto Sukhoi, \\
&\}
\end{aligned}$$