

Concordia University
Department of Computer Science and Software
Engineering
SOEN 331-S:
Formal Methods for Software Engineering

Assignment 1

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1 General information

Date posted: Thursday 29 September, 2022.

Date due: Monday, 9 October, 2022, by 23:59.

Weight: 7.5% of the overall grade.

2 Introduction

You should find one partner and between the two of you should designate a team leader who will submit the assignment electronically. There are **5** problems in this assignment, with a total weight of **75** points.

3 Ground rules

This is an assessment exercise. You may not seek any assistance while expecting to receive credit. **You must work strictly within your team and seek no assistance for this assignment (e.g. from the teaching assistants, fellow classmates and other teams or external help).** You should **not** discuss the assignment during tutorials. I am available to discuss clarifications in case you need any.

Both partners are expected to work relatively equally on each problem. Accommodating a partner who did not contribute will result in a penalty to both. You cannot give a “free pass” to your partner, with the promise that they will make up by putting more effort in a later assignment.

You are expected to start learning \LaTeX and use it for this assignment.

If there is any problem in the team (such as lack of contribution, etc.), the team leader must contact me as soon as the problem appears.

4 Problems

4.1 Predicate logic 1 (10 pts)

In the domain of all people in a 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?

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

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

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

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

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

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

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

4.2 Predicate logic 2 (10 pts)

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.

4.3 Unordered and ordered structures (15 pts)

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.
2. Is $\mathbb{P}OS$ a legitimate type? Explain.
3. What does the following statement signify? $My_OS : OS$. Is the statement acceptable? Explain.
4. Is $MacOS \in \mathbb{P}OS$? Explain.
5. Is OS a legitimate type?
6. Is $\{\}$ $\in \mathbb{P}OS$? Explain.
7. Is $\{Linux, BSD\} \in \mathbb{P}OS$? Explain.
8. Is $\{\{\}\} \in \mathbb{P}OS$?
9. Is $\{\} \in OS$? Explain.
10. If we define variable $My_computer : \mathbb{P}OS$, is $\{\}$ a legitimate value for variable $My_Computer$? Explain.
11. If we stated that $My_computer = \{Windows\}$, would the statement make $My_Computer$ an atomic variable?
12. Is $\{\{BSD, MacOS\}\} \subset \mathbb{P}OS$? Explain.
13. Is $My_OS \subset \mathbb{P}OS$? Explain.
14. Is $\{\{BSD, MacOS\}\} \in \mathbb{P}OS$?

4.4 Relational calculus 1 (15 pts)

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

1. Flights are unique.
2. Each flight is associated to a single airline, e.g. AA333 is an American Airlines flight.
3. The system can support new flights to be associated to an existing airline, or existing flights to be deleted.
4. 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:

$$\begin{aligned} \text{map} = & \\ & \{ \\ & \quad \text{AA333} \mapsto \text{American Airlines}, \\ & \quad \text{AY29} \mapsto \text{Finnair}, \\ & \quad \text{TS261} \mapsto \text{Air Transat}, \\ & \quad \text{TS765} \mapsto \text{Air Transat} \\ & \} \end{aligned}$$

1. Is `map` a binary relation? Explain.
2. Is `map` a function? Explain and if Yes, determine the type of the function.
3. Define the precondition for operation `add`, that adds a new flight-airline pair.

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

4. Provide two alternative definitions for the core functionality of operation `add`.
5. What would be the result of calling operation `add` with `flight? = TS765`, and `airline? = American Airlines`?

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

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

flight? = AA333,
airline? = Air Canada

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

4.5 Relational calculus 2 (25 pts)

Consider the following binary relation:

$$\textit{airplanes} : \textit{Model} \leftrightarrow \textit{Manufacturer}$$

where

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

1. What is the value of the following expression:

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

2. What is the value of the following expression:

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

3. What is the value of the following expression:

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

4. What is the value of the following expression:

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

5. What is the value of the following expression:

$$airplanes \oplus \{Su_{80} \mapsto Sukhoi\}$$

Comment on the deployment of the expression in the context of a database table.

5 What to submit

You must prepare all your solutions in L^AT_EX and produce a single pdf file. You may use the .tex template provided. Name both your .tex and .pdf assignment files after the Concordia id of the person who will submit, e.g. 123456.pdf, and submit both .tex and .pdf files at the Electronic Assignment Submission portal at

(<https://fis.encs.concordia.ca/eas>)

under **Assignment 1**.

No late submissions will be accepted.

END OF ASSIGNMENT.
