Concordia University

Department of Computer Science and Software Engineering

SOEN 331 - S

Formal Methods for Software Engineering

Assignment 1: Fundamentals

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1 General information

Date posted: Thursday 30 September, 2021.

Date due: Thursday, 14 October, 2021, by 23:59.

Weight: 15% of the overall grade.

2 Introduction

You should form a team of **three** members. Each team should designate a leader who will submit the assignment electronically. In case you cannot find a team, please contact me and I will assign you to one. There are **7** problems in this assignment, with a total weight of **100** points. You must prepare all your solutions in LaTeX and produce a single `pdf` file. Name the file after the Concordia id of the person who will submit, e.g. `123456.pdf`.

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)**. Please note that you should **not** discuss the assignment during tutorials. I am available to discuss clarifications in case you need any.

All team members are expected to work relatively equally on each problem. The team leader has the responsibility to ensure that the team does not violate this rule. **In your submission, you must include only the names of those team members who contributed to the assignment.** Accommodating someone who did not contribute will result in a penalty.

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

4 Problems

4.1 Propositional logic (10 pts)

You are shown a set of four cards placed on a table, each of which has a **letter** on one side and a **symbol** on the other side. The visible faces of the cards show the letters **L** and **A**, and the symbols □, and ♢.

Which card(s) must you turn over in order to test the truth of the proposition that *"If a card has a consonant on one side, then it has the symbol ♢ on the other side"*? Explain your reasoning <u>in detail</u> by deciding for <u>each</u> card whether it should be turned over and why. In your answers, apply any and all appropriate validating or non-validating patterns where applicable.

4.1.1 Propositional logic answer

We have two statements:

S1: The card has a consonant

S2: The symbol is ♢

$S1 \to S2$

Card ♢: Implication does not necessarily entail causation. So even if the card is a ♢ the othe side value could be L or A. It is not the card to turn.

Card □: This card does not satisfy the second statement that the card is a ♢. So we cannot evaluate the second statement. It is not the card to turn.

Card A: Since this card is a vowel, it will not help in satisfying the proposition of S1. It is not the card to turn.

Card L: This card will help answer the question because it satisfy the premise that the card has a consonant. We can check the back to validate S2. This should be the card to turn.

4.2 Predicate logic 1 (10 pts)

In the domain of all people, consider the predicate *disclosed(a, b)* that is interpreted as *"a has disclosed a secret to b."*

1. How are the following two expressions translated into plain English? Are the two expressions logically equivalen $\forall\, a\, \exists\, b\;\; asks(a, b)$, and $\exists\, b\, \forall\, a\;\; asks(a, b)$.

   - $\forall\, a\, \exists\, b\;\; disclosed(a, b)$.
   - $\exists\, b\, \forall\, a\;\; disclosed(a, b)$.

2. Can we claim that $\forall\, a\, \exists\, b\;\; disclosed(a, b) \rightarrow \exists\, b\, \forall\, a\;\; disclosed(a, b)$? Discuss in detail.

3. Can we claim that $\exists\, b\, \forall\, a\;\; disclosed(a, b) \rightarrow \forall\, a\, \exists\, b\;\; disclosed(a, b)$? Discuss in detail.

4.2.1 Problem 2 answer

1. translation

   $\forall\, a\, \exists\, b\;\; disclosed(a, b)$: For all a, there exist a b such that a has asked b out on a date.

   $\exists\, b\, \forall\, a\;\; disclosed(a, b)$: There exists a b such that all a asked b out on a date.

2. Can we claim that $\forall\, a\, \exists\, b\;\; disclosed(a, b) \rightarrow \exists\, b\, \forall\, a\;\; disclosed(a, b)$? Discuss in detail.

3. Can we claim that $\exists\, b\, \forall\, a\;\; disclosed(a, b) \rightarrow \forall\, a\, \exists\, b\;\; disclosed(a, b)$? Discuss in detail.

4.3 Predicate logic 2 (10 pts)

Consider the subject “x is a person” and the predicate “x is a mortal”, together with the following list of categorical propositions:

- “No person is immortal.”
- “All people is immortal.”
- “Some people are mortal.”
- “Some people are not mortal.”

1. “Identify each categorical statement with its name (i.e. letter description)”.

   answer:

   ”No person is immortal.”: A Form

   ”All people are immortal.”: E Form

   ”Some people are mortal.”: I Form

   ”Some people are not mortal.”: O Form

2. “Identify universal statements.”

   answer:

   ”No person is immortal.” and ”All people are immortal.”

3. “Identify particular statements.”

   answer:

   ”Some people are mortal.” and ”Some people are not mortal.”

4. “Identify affirmative statements”

   answer:

   ”No person is immortal.” and ”Some people are mortal.”

5. “Identify negative statements.”

   answer:

   ”All people are immortal.” and ”Some people are not mortal.”

6. “Identify statements with opposite truth values”

   answer:

7. “Identify statements that cannot both be true, but could both be false.”

   answer:

8. “Identify statements that cannot both be false but could both be true.”

   answer:

9. “Identify pairs of super-subaltern statements.”

   answer:

4.4 Ordered structures (10 pts)

Consider a list $\Lambda = \langle w, x, y, z \rangle$, deployed to implement a stack Abstract Data Type.

1. Let the head of Λ correspond to the topmost position of the Stack. Implement the body of operations `push(el,` Λ`)` and `pop(`Λ`)` (let return element be held in variable topmost) using list construction operations. In both cases a) we assume that appropriate preconditions exist, and b) we can refer to Λ' as the state of the list upon successful termination of one of its operations.

   answer:

   `push(el,` Λ`)` can be written as $\Lambda' = cons(el, \Lambda) = \langle el, w, x, y, z \rangle$.

   `pop(`Λ`)` can be written as $head(\Lambda) = element = w$ and $\Lambda' = tail(\Lambda) = \langle x, y, z \rangle$,

2. Let the last element of Λ correspond to the topmost position of the Stack. Implement the body of both operations as above. When applicable, use control flow statements in your answer.

4.5 Unordered structures and type declarations (10 pts)

4.6 Relational calculus 1 (25 pts)

4.7 Relational calculus 2 (25 pts)

1. Given the above Relation,

   a) Domain: Model

   b) Range: Brand

2. Given the following expression:

   {galaxyA01, galaxyJ2Core, redmi8} $\lhd$ cellphones

   a) $\lhd$ is a domain restriction, it selects pairs according to the first element

   b)

   {galaxyA01, galaxyJ2Core, redmi8} $\lhd$ cellphones = {
   galaxyA01 $\mapsto$ samsung,
   galaxyJ2Core $\mapsto$ samsung,
   redmi8 $\mapsto$ xiaomi
   }

   c) This operator is used in database queries

3. Given the following expression:

4. Given the following expression:

   {mate10pro, iphoneSE, galaxyJ2Core} $\ntriangleleft$ cellphones

   a) $\ntriangleleft$ is a domain subtraction, it removes all specified element from the domain of the definition

   b)

   cellphones' = {mate10pro, iphoneSE, galaxyJ2Core} $\ntriangleleft$ cellphones = {
   galaxyA21s $\mapsto$ samsung
   mate10 $\mapsto$ huawei
   galaxyA01 $\mapsto$ samsung
   iphone12ProMax $\mapsto$ apple
   redmi6A $\mapsto$ xiaomi

redmi8 $\mapsto$ xiaomi

}

c) This operator would be deployed when we want to delete elements from the database.

5. Given the following expression:

6. Given the following expression:

cellphones $\bigoplus$ {galaxyA51 $\mapsto$ samsung, mate9 $\mapsto$ huawei}

a) $\bigoplus$ is a relational overide

b)

cellphones $\bigoplus$ {galaxyA51 $\mapsto$ samsung, mate9 $\mapsto$ huawei} = {

galaxyA21s $\mapsto$ samsung

mate10 $\mapsto$ huawei

mate10pro $\mapsto$ huawei

galaxyA01 $\mapsto$ samsung

iphone12ProMax $\mapsto$ apple

iphoneSE $\mapsto$ apple

galaxyJ2Core $\mapsto$ samsung

redmi6A $\mapsto$ xiaomi

redmi8 $\mapsto$ xiaomi

galaxyA51 $\mapsto$ samsung

mate9 $\mapsto$ huawei

}

c) This operator would be used in the event that we want to add or modify elements in the database.

d) The expression doesn't have a permanent effect. If we want to have a permanent effect, we would need to have an assignment operation as such:

cellphones' = cellphones $\bigoplus$ {galaxyA51 $\mapsto$ samsung, mate9 $\mapsto$ huawei}

We need to assign the value of the expression to cellphone to have permanent effect.

5 What to submit

Please submit your `pdf` file at the Electronic Assignment Submission portal

(`https://fis.encs.concordia.ca/eas`)

under **Theory Assignment 1**.