CS 511
Formal Methods for High-Assurance Software Engineering
Homework Assignment 04

Out: 27 September 2024
Due: Thursday, 3 October 2024, by 11:59 pm

Repeated below are administrative issues already mentioned in the handout of Assignment 01:

- You need to open a Gradescope account, after which you need to add yourself to the CS511 roster for this semester. The entry code for CS511, Fall 2023, is `WWX2NW`.

  If you want to read more on adding yourself to the CS511 roster, go to Adding a Course .

- You also need to create a *GitHub repository* where you store your solutions for *coding exercises with* Lean_4.

  To create a GitHub repository, you need to open a GitHub account. Instructions for how to do this are at the following webpages: Set Up a GitHub Account and Create a GitHub Repository.

- Typically, each weekly assignment consists of two parts:

  1. One part includes ***hand exercises***, *i.e.* ***pencil-and-paper exercises***, and
  2. One part includes ***coding exercises*** in Lean_4.

  And each of the two parts will consist of:

  - **2 easy exercises**, and
  - **1 demanding exercise**, which we will call a **problem**,

  for a total of **4 easy exercises** and **2 problems** in each weekly assignment.

- Typeset your solutions with Latex to produce a single '`.pdf`' file containing:

  1. All your solutions for the ***hand exercises***, and
  2. Links to your ***coding exercises***, which are stored in your GitHub repository. (You should insert the links as active, *i.e.* clickable, *hyperlinks* in your '`.pdf`' file.)

  It is the '`.pdf`' file produced with Latex that you will submit in Gradescope.

  You do not need to use any particular format in naming your '`.pdf`' file, because Gradescope will keep track of who is submitting it. Nonetheless, it is nice to use suggestive names in case of a mishap and we need to recover your file. So, here is a possible naming:

  ```
  <your last name>_<your first name>.hw01.pdf
  ```

  For example, for myself, I would call my file '`kfoury_assaf.hw01.pdf`'.

1 By Hand

Exercise 1 [EML.Chapter 1.pdf, page 15-16]: Do part 1 of Exercise 27. □

Exercise 2 [Lecture Slides 13, page 19]: Do the exercise on that page.
It says "Formalize this idea", which is in parts 1 and 2 of the exercise. But "formalize" here does NOT mean at the formal level, within one of our formal logics so far (propositional logic and quantified propositional logic). Take "formalize" to mean "be as rigorous and precise as you can at the meta level". □

PROBLEM 1 [EML.Chapter 1.pdf, page 15-16]: Do parts 2, 3, and 4 of Exercise 27. □

2 With Lean_4

Exercise 3 From Macbeth's book:

1. Example 2.5.5,
2. Example 2.5.6,
3. Example 2.5.7 .

Hint: These should be easy if you read the book. Use existential quantifiers. □

Exercise 4 From Macbeth's book:

1. Exercise 3.1.10.3 ,
2. Exercise 4.1.10.1 ,
3. Example 4.1.3 .

Hint: These use existential and universal quantifiers. The existential quantifiers are used in both context and goal, but universal quantifiers only in context. □

PROBLEM 2 From Macbeth's book:

1. Exercise 3.2.9.2 ,
2. Exercise 3.2.9.5 ,
3. Exercise 3.2.9.6 .

Hint: The first will be hard unless you use the lemma listed in the book. The other two involve some computation, but they should be easy if you make use of scratch paper while solving. The very last one shows that order matters when rewriting and is similar otherwise. □