CS 511
Formal Methods for High-Assurance Software Engineering
Homework Assignment 02

Out: 13 September 2024
Due: Thursday, 19 September 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`'.

Reminder about doing or not doing a term project:

This is a slight adjustment to what you need to do to satisfy the requirement of a *term project*:

- Either you choose a *term project* in consultation with Assaf and Aaron, in which case you only need to do the **4 easy exercises** in each weekly assignment,
- Or you choose to completely forego doing a *term project*, in which case you will have to do the **4 easy exercises** plus the **2 problems** in each weekly assignment.

1 By Hand

Exercise 1 Go to page 9 in ***Lecture Slides 06***. Your task is to carefully write all the details of the proof by *structural induction*. These details are not included in the slides. □

Exercise 2 [LCS, page 87]: Exercise 1.4.15.

Hint: You may find it helpful to review pages 20 and 21 in ***Lecture Slides 02***. □

PROBLEM 1 Show that any of the three rules $\{(\text{LEM}), (\text{PBC}), (\neg\neg\text{E})\}$ are interderivable.

Hint 1: One way is to consider $\binom{3}{2} = 3$ cases, one for each pair from the set of three rules, with each pair involving two derivations, for a total of $6 = 3 \times 2$ derivations. A simpler approach requires only 3 derivations:

(a) (PBC) is derivable from ($\neg\neg$E),

(b) (LEM) is derivable from (PBC),

(c) ($\neg\neg$E) is derivable from (LEM).

Schematically, you have to show that $(\neg\neg\text{E}) \Rightarrow (\text{PBC}) \Rightarrow (\text{LEM}) \Rightarrow (\neg\neg\text{E})$.

Hint 2: Consult page 25 in [LCS], where the natural-deduction derivation for part (a) in *Hint 1* is given. So, your task is to find natural-deduction derivations for parts (b) and (c) in *Hint 1*. □

2 With Lean_4

Exercise 3 For each of the three examples in the following three sections of Macbeth's book, your task is to remove '`sorry`' and insert appropriate LEAN_4 tactics:

1. Example 1.4.6,
2. Example 2.1.3,
3. Example 2.1.7 . □

Exercise 4 For each of the three examples in the following three sections of Macbeth's book, your task is to remove '`sorry`' and insert appropriate LEAN_4 tactics:

1. Exercise 2.1.9 (1),
2. Exercise 2.1.9 (3),
3. Exercise 2.2.4 (1) . □

PROBLEM 2 For each of the three examples in the following three sections of Macbeth's book, your task is to remove '`sorry`' and insert appropriate LEAN_4 tactics:

1. Example 2.1.8 ,
2. Exercise 2.1.9 (2) ,
3. Exercise 2.2.4 (2) . □