CS 511
Formal Methods for High-Assurance Software Engineering
Homework Assignment 07

Out: 18 October 2024
Due: Thursday, 24 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 Open **Lecture Slides 29, I, Analytical Tableaux for Classical First-Order Logic**. Do Exercise 1 on page 14.

Hint: To show that $\{\psi_1, \psi_2, \psi_3\} \models \varphi$ is equivalent to showing $\{\psi_1, \psi_2, \psi_3\} \vdash \varphi$ (by completeness), which is equivalent to showing $\vdash (\psi_1 \wedge \psi_2 \wedge \psi_3) \rightarrow \varphi$. These equivalences hold for formal proofs carried out according to the rules of *natural deduction*, and they hold again when *analytic tableaux* are used as a formal-proof system. □

Exercise 2 Open **Lecture Slides 29, I, Analytical Tableaux for Classical First-Order Logic**. Do Exercise 2 on page 14.

Hint: Review the hint in the preceding exercise. □

PROBLEM 1 Open **EML.Chapter_6.pdf**. Do part Exercise 113 on page 69.

Hint: This is a continuation of the discussion in lecture yesterday (Thursday, October 17). As suggested in lecture, read carefully and understand Example 112 on pages 68-69 before embarking on Exercise 113. □

2 With Lean_4

Exercise 3 From Macbeth's book:

1. Exercise 5.1.7.6 ,
2. Exercise 5.1.7.8 ,
3. Exercise 5.1.7.9 . □

Exercise 4 From Macbeth's book:

1. Exercise 5.1.7.11 ,
2. Exercise 5.1.7.12 ,
3. Exercise 5.1.7.13 . □

PROBLEM 2 From Macbeth's book:

1. Exercise 5.1.7.14 ,
2. Exercise 5.2.7.2 . □

We will post an appropriate Lean 4 template for this homework on Piazza by the end of Friday, October 18 (today). □