CS 511
Formal Methods for High-Assurance Software Engineering
Homework Assignment 06

Out: 11 October 2024
Due: Thursday, 17 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 22, FO Definability, Appendix**. Do Exercise 3 on page 2.

Hint: Carefully use the hint, as well as the special case given in lecture on Thursday, October 10.

Use $\approx$, instead of $=$, for the formal symbol whose interpretation is equality. In LaTeX, you can typeset $\approx$ with `\approx`. □

Exercise 2 Open **Lecture Slides 22, FO Definability, Appendix**. Do Exercise 10 on page 3.

Hint 1: Review how we showed, in lecture on Thursday October 10, that the unary predicate '`prime`' was first-order definable in in structure $(\mathbb{N}; =, <, +, \cdot, S, 0)$. See pages 15-16 in **Lecture Slides 21** where '`prime`' is called '`pr`'.

Hint 2: You case use any of the preceding exercises in **Lecture Slides 22, FO Definability, Appendix** as "lemmas" without proving them again, *i.e.*, use the statements of the exercises as premises that you do not need to prove. □

PROBLEM 1 Open **EML.Chapter_4.pdf**. Do part 2 and part 3 in Exercise 71 on page 46.

Hint: You will have to do a fair amount of reading in the same chapter before doing this problem, in particular, you should carefully study the material in Example 70 right before Exercise 71. However, by the time you have finished your reading, your answers will be relatively easy to write. □

2 With Lean_4

Exercise 3 From Macbeth's book:

1. Exercise 3.4.5.6 ,
2. Exercise 3.4.5.7 . □

Exercise 4 From Macbeth's book:

1. Exercise 4.4.6.2 ,
2. Exercise 4.4.6.3 . □

PROBLEM 2 From Macbeth's book:

1. Example 4.5.4 ,
2. Example 4.5.5 ,
3. Example 4.5.6 . □

We will post an appropriate Lean 4 template for this homework on Piazza by the end of Friday, October 11 (today). □