Homework Assignment #7

Due Time/Date

This assignment is due 2:10PM Tuesday, May 12, 2020. Late submission will be penalized by 20% for each working day overdue.

How to Submit

Please use a word processor or scan hand-written answers to produce a single PDF file. Name your file according to this pattern: "b057050xx-hw7". Upload the PDF file to the Ceiba course site for Theory of Computing 2020: https://ceiba.ntu.edu.tw/1082theory2020. You may discuss the problems with others, but copying answers is strictly forbidden.

Problems

(Note: problems marked with "Exercise X.XX" or "Problem X.XX" are taken from [Sipser 2013] with probable adaptation.)

1. (Exercise 3.2; 10 points) Consider the Turing machine for $\{w\#w \mid w \in \{0,1\}^*\}$ discussed in class. Give the sequence of configurations (using the notation uqv for a configuration) that the machine goes through when started on the input 01#01.

2. (20 points) Give a *formal* description (with a state diagram) of a Turing machine that decides the language $\{w \in \{0,1\}^* \mid w \text{ is nonempty and contains twice as many 1s as 0s}\}$.

3. (Exercise 3.7; 10 points) Explain why the following is not a description of a legitimate Turing machine.

   M_{bad} = "The input is a polynomial p over variables $x_1, \ldots, x_k$:

   (a) Try all possible settings of $x_1, \ldots, x_k$ to integer values.
   (b) Evaluate p on all of these settings.
   (c) If any of these settings evaluates to 0, *accept*; otherwise, *reject*."

4. (Problem 3.16; 10 points) Show that the collection of decidable languages is closed under *concatenation*.

5. (Problem 3.18; 10 points) A ***Turing machine with a doubly infinite tape*** is similar to an ordinary Turing machine, but its tape is infinite to the left as well as to the right. The tape is initially filled with blanks except for the portion that contains the input. Computation is defined as usual except that the head never encounters an end to the tape, as it moves left. Show that this type of Turing machine recognizes the class of Turing-recognizable languages.

6. (Problem 3.20; 20 points) A ***Turing machine with stay put instead of left*** is similar to an ordinary Turing machine, but the transition function has the form

$$\delta : Q \times \Gamma \to Q \times \Gamma \times \{R, S\}$$

At each point the machine can move instead its head right or let it stay in the same position. Show that this Turing machine variant is *not* equivalent to the usual version. What class of languages do these machines recognize?

7. (Problem 3.22; 20 points) Let a k-PDA be a pushdown automaton that has k stacks. Thus a 0-PDA is an NFA and a 1-PDA is a conventional PDA. You already know that 1-PDAs are more powerful (recognizing a larger class of languages) than 0-PDAs.

   (a) Show that 2-PDAs are more powerful than 1-PDAs.

   (b) Show that 3-PDAs are *not* more powerful than 2-PDAs. (Hint: simulate a Turing machine tape with two stacks.)