CSCE-433 Formal Languages & Automata
CSCE-627 Theory of Computability

Spring 2022

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Assignment # 4
(Due March 11, 2022)

Instructions.

- Your assignment must be typed using your favorite word processor. You may draw diagrams by hand, but only if you are very neat and the diagram is legible.
- Turn in a PDF file of your homework on Canvas.
- Homework is always due at the **beginning** of the class on the due day.

Questions.

1. (20 points) Give a regular (i.e., left-linear) grammar for each of the following languages:
   (a) all strings over $\{a, b\}$ that do not contain ab;
   (b) (CSCE 433 students only) all strings over $\{a, b\}$ that contain at least one a and every a is immediately followed by at least one b;
   (c) (CSCE 627 students only) all strings over $\{a, b\}$ with an even number of a's and an odd number of b's

2. (10 points) Convert the following regular grammar into an NFA:

$$\begin{aligned} S &\rightarrow aS|aX|a \\ X &\rightarrow bS|aY \\ Y &\rightarrow bS \end{aligned}$$

3. (20 points) Given informal descriptions and state diagrams of pushdown automata for the following languages. (For examples of informal descriptions, see the solutions to Exercise 2.7 on page 160 of the textbook.)
   (a) $L_1 = \{wcw^R | w \in \{a, b\}^*\}$. So the set of terminals is $\{a, b, c\}$;
   (b) (CSCE 433 students only) L_2 is the set of all binary strings with twice as many 0's as 1's (with no restriction on the order in which the 0's and 1's occur);
   (c) (CSCE 627 students only) $L_3 = \{0^n 1^n | n \geq 1\} \cup \{0^n 1^{2n} | n \geq 1\}$.

4. (20 points) Convert the following CFG into an equivalent PDA:

$$\begin{array}{rcl} E & \to & E + T \mid T \\ T & \to & T * F \mid F \\ F & \to & (E) \mid a \end{array}$$

5. (30 points) Use the pumping lemma for context-free languages to prove that the following languages are not context-free:

(a) $\{0^n 1^n 0^n 1^n \mid n \geq 0\}$;

(b) $\{w_1 c w_2 c \ldots c w_k \mid k \geq 2$, each $w_i \in \{a, b\}^*$ and $w_i = w_j$ for some $i \neq j\}$. The alphabet is $\{a, b, c\}$. Each string in the language consists of at least two substrings of a's and b's, the substrings are separated by c's, and at least two of the substrings are equal;

(c) the set of all strings over $\{a, b, c, d\}$ such that the number of a's equals the number of b's, and the number of c's equals the number of d's. Note that there is no restriction on the order in which the symbols occur.