CptS 317: Automata and Formal Languages
Mid-Term Exam 2

Released: March 29, 2021, 10:10 am
Submission deadline: March 30, 2021, 4:00 pm

Instructions:

1. Remember to write your name and WSU ID number on your answer sheet.
2. There are 5 questions on this exam (they are on the second page of this document). Some of the questions have multiple parts.
3. Each question has a point value listed in parentheses next to the problem number. Questions are not equally weighted, however questions with multiple parts will have each part equally weighted. The total value of all questions is 100 points.
4. You may type-up or hand-write your solution. In either case, submit a PDF of the document on Canvas by the indicated deadline. If you hand-write, please make sure that your writing is legible and that the scan/picture of your document is clear.

1. (30 pts) The following is a context-free grammar that is based on the English language (with some deviations - pronouns such as "their" are not considered articles in English). Note that ⟨SENTENCE⟩ is the start state:

$$\begin{aligned}
\langle \text{SENTENCE} \rangle &\rightarrow \langle \text{NOUN-PHRASE} \rangle \langle \text{VERB-PHRASE} \rangle \\
\langle \text{NOUN-PHRASE} \rangle &\rightarrow \langle \text{COMPLEX-NOUN} \rangle | \langle \text{COMPLEX-NOUN} \rangle \langle \text{PREP-PHRASE} \rangle \\
\langle \text{VERB-PHRASE} \rangle &\rightarrow \langle \text{COMPLEX-VERB} \rangle | \langle \text{COMPLEX-VERB} \rangle \langle \text{PREP-PHRASE} \rangle \\
\langle \text{PREP-PHRASE} \rangle &\rightarrow \langle \text{PREP} \rangle \langle \text{COMPLEX-NOUN} \rangle \\
\langle \text{COMPLEX-NOUN} \rangle &\rightarrow \langle \text{NOUN} \rangle | \langle \text{ARTICLE} \rangle \langle \text{NOUN} \rangle \\
\langle \text{COMPLEX-VERB} \rangle &\rightarrow \langle \text{VERB} \rangle | \langle \text{VERB} \rangle \langle \text{NOUN-PHRASE} \rangle \\
\langle \text{ARTICLE} \rangle &\rightarrow \text{the} \mid \text{their} \\
\langle \text{NOUN} \rangle &\rightarrow \text{assignments} \mid \text{canvas} \mid \text{pride} \mid \text{students} \mid \text{vaccines} \\
\langle \text{VERB} \rangle &\rightarrow \text{submit} \mid \text{take} \\
\langle \text{PREP} \rangle &\rightarrow \text{via} \mid \text{with}
\end{aligned}$$

   a) Show that the grammar has two leftmost derivations for the sentence "the students take their vaccines with pride".
   b) Remove one rule from the grammar that will allow the same sentence to be parsed, but without ambiguity.
   c) Show that after you have removed the rule in part b, the phrase "the students submit their assignments via canvas" has only one leftmost derivation in the resulting the grammar.

2. (20 points) Give unambiguous CFGs that generate the following languages:

   a) $\{w|$ the number of 0s and 1s in w are equal$\}$
   b) $\{w|$ the number of 0s in w is at least the number of 1s in $w\}$

3. (15 points) Provide a pushdown automata that accepts the language generated by the following context free grammar:

$$\begin{aligned}
S &\rightarrow (O_E_E) \\
E &\rightarrow S|N \\
N &\rightarrow 0|1|NN \\
O &\rightarrow +|-|*|/
\end{aligned}$$

4. (15 points) Convert the following CFG into Chomsky Normal Form:

$$\begin{aligned}
A &\rightarrow BAB|B|\epsilon \\
B &\rightarrow 00|\epsilon
\end{aligned}$$

5. (20 points) State True or False for each of the following questions. If your answer is False, provide a brief justification.

   a) For any regular language, there is a CFG that generates that language.
   b) The Table Filling algorithm can be used to find an NFA with a minimum number of states for a regular language.
   c) Deterministic PDAs and Nondeterministic PDAs describe the same class of languages.
   d) The class of Deterministic Context Free Languages is closed under union.
   e) The class of Deterministic Context Free Languages is **not** closed under star.