CS3311 Homework 9   Due date: Wednesday, November 8, 2017, by class time, 1:05pm
Submission: Typed, pdf on Canvas (scanned submissions are not allowed)

The answers must be the original work of the author. While discussion with others is permitted and en-couraged, the final work should be done individually. You are not allowed to work in groups. You are allowed to build on the material supplied in the class. Any other source must be specified clearly.

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1. *(5 + 5 + 10 points)* Consider the following grammar G over $\Sigma = \{a, b\}$.

$$S \rightarrow AB \,|\, aB$$
$$A \rightarrow aB \,|\, BS$$
$$B \rightarrow bB \,|\, b \,|\, \lambda$$

(a) Transform the grammar into $G1$ so that the recursion to the start symbol is removed.

(b) Show the set of nullable variables in the **new grammar** $G1$.

(c) Construct an essentially noncontracting grammar G_L (with a non-recursive start symbol) equiv-alent to $G1$. An "essentially noncontracting grammar" is a grammar that has no λ-rules.

2. *(5+5 points)* Consider the following grammar G over $\Sigma = \{a, b, e, f\}$. Note that the grammar does not contain λ-rules except at S.

$$S \rightarrow aSb \,|\, DEF \,|\, D \,|\, \lambda$$
$$D \rightarrow E \,|\, EF \,|\, abEF$$
$$E \rightarrow eEff \,|\, a \,|\, F$$
$$F \rightarrow ffFe \,|\, a$$

(a) Use algorithm 4.3.1 to construct the CHAIN sets for the variables in V.

(b) Construct an equivalent grammar G_c that does not contain chain rules.

3. *(10+10 points)* Consider the following grammar G over $\Sigma = \{a, b, c, d\}$.

$$S \rightarrow a \,|\, aA \,|\, BC$$
$$A \rightarrow aB \,|\, b$$
$$B \rightarrow Aa$$
$$C \rightarrow cCD$$
$$D \rightarrow ddd$$

(a) Construct the TERM set for G.

(b) Use the TERM set to construct an equivalent grammar G_T that does not contain variables that do not generate strings of terminals.

Please turn the page over for additional questions.

4. *(10+10 points)* Consider the following grammar G where Σ contains every word listed in the rules: $\Sigma = \{$ Michigan, Tech, ..., cool $\}$.

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S →  Michigan Tech CS gives N | Having a graduate degree is R
T →  Being in a computing field is D
N →  BSc degrees | MSc degrees | PhD degrees
R →  fun | intellectually challenging |
     financially rewarding |
     not as hard as one would think |
     a worthwhile option to explore
D →  fun | awesome | cool
```

(a) Construct the REACH set for G.

(b) Use the REACH set to construct an equivalent grammar G_U that does not contain unreachable variables.

5. *(20 points)* Convert the following grammar G over $\Sigma = \{a, b\}$ into Chomsky normal form. Note that G already satisfies the conditions on the start symbol S, λ-rules, useless symbols, and chain rules. Show your steps clearly.

$$S \to bT \qquad T \to aAA \mid AbAT \qquad A \to aT \mid bT \mid a$$

6. *(10 points)* Remove left recursion from the following grammar using the method described in class. $\Sigma = \{a, b\}$.

$$S \to A \mid B$$
$$A \to AAA \mid a \mid B$$
$$B \to BBb \mid b$$