

# CS344: Programming Languages

## Homework 4

### Required Problems

1. Give context-free grammars generating the following languages:

(a)  $L_1 = \{a^n b^p \mid 0 \leq p < n\}$ .

(b)  $L_2 = \{a^n b^n c^m d^m \mid n, m \in \mathbb{N}\}$

2. Convert your two grammars from problem 1 to Chomsky Normal Form using the conversion algorithm given in class.
3. Give a (relatively simple) LL(1) grammar for the language which consists of all strings of properly balanced parenthesis and brackets. Use your grammar to construct a parse tree for the string  $( [ ] ( [ ] ) ) [ ] ( ( ) )$ .

4. Consider the following grammar (where non-terminals are in italics):

$$\begin{aligned}
 \textit{stmt} &\rightarrow \textit{assignment} \\
 &\rightarrow \textit{subroutine\_call} \\
 \textit{assignment} &\rightarrow \textit{id} := \textit{expr} \\
 \textit{subroutine\_call} &\rightarrow \textit{id} ( \textit{arg\_list} ) \\
 \textit{expr} &\rightarrow \textit{primary} \textit{expr\_tail} \\
 \textit{expr\_tail} &\rightarrow \textit{op} \textit{expr} \\
 &\rightarrow \epsilon \\
 \textit{primary} &\rightarrow \textit{id} \\
 &\rightarrow \textit{subroutine\_call} \\
 &\rightarrow ( \textit{expr} ) \\
 \textit{op} &\rightarrow + \mid - \mid * \mid / \\
 \textit{arg\_list} &\rightarrow \textit{expr} \textit{arg\_tail} \\
 \textit{arg\_tail} &\rightarrow , \textit{arg\_list} \\
 &\rightarrow \epsilon
 \end{aligned}$$

- (a) Construct a parse tree for the input `foo(a,b)`.
- (b) Give a canonical (rightmost) derivation of this same string.
- (c) Prove the grammar is not LL(1).
- (d) Modify the grammar so that it is LL(1).