Programming Languages and Computation

Week 3: LL(1) Grammars

** 1. Consider the following grammar for arithmetic expressions:

$$\begin{array}{rcll} E & ::= & \mathsf{num} & (1) \\ & | & \mathsf{id} & (2) \\ & | & E + E & (3) \\ & | & E * E & (4) \\ & | & (E) & (5) \end{array}$$

The 6 terminal symbols of this grammar are:

$$\mathsf{num} \quad \mathsf{id} \quad + \quad * \quad (\quad)$$

The nullable, first and follow sets for the nonterminals are:

Nonterminal	Nullable?	First	Follow
E	×	num, id, (	+, *,)

(a) For each of the rules (1) – (5), construct the first set of the right-hand side of the rule.

(b) Construct the parsing table for this grammar.

(c) What do the rule conflicts (cells of the parsing table containing more than one rule) of this gammar and the previous grammar have in common? Without constructing the parsing table, argue that the following grammar is sure to have a rule conflict:

$$\begin{array}{rcl} X & ::= & \mathsf{a} \\ & | & \mathsf{b} \\ & | & X\ \mathsf{c} \end{array}$$

* 2. Consider the following grammar for arithmetic expressions, whose terminals are the same as above:

$$\begin{array}{rcll} E & ::= & \mathsf{num} & (1) \\ & | & \mathsf{id} & (2) \\ & | & (\ F\ ) & (3) \\ F & ::= & +\ E\ E & (4) \\ & | & *\ E\ E & (5) \end{array}$$

The first, follow and nullable sets of the nonterminals can be described by:

Nonterminal	Nullable?	First	Follow
E	×	num, id, (	), num, id, (
F	×	+, *	)

(a) Construct the first set for each of the right-hand sides of rules in the grammar.

(b) Construct the parsing table for the grammar.

(c) Is the grammar LL(1)?

(d) Is num + num ∗ id derivable in this grammar? If so, give a derivation.

* 3. Consider the following grammar for arithmetic expressions, whose terminals are as above:

$$\begin{array}{rcl} E & ::= & \mathsf{num}\ F \\ & | & \mathsf{id}\ F \\ & | & (\ E\ )\ F \\ F & ::= & +\ E \\ & | & *\ E \\ & | & \epsilon \end{array}$$

The nullable, first and follow sets can be described by:

Nonterminal	Nullable?	First	Follow
E	×	num, id, (	)
F	✓	+, *	)

(a) Construct the first set of each of the right-hand sides of rules in the grammar.

(b) Construct the parsing table of the grammar.

(c) Is the grammar LL(1)?

(d) Is num + num ∗ id derivable in this grammar? If so, give a derivation.

** 4. Give a CFG that describes the language of all subsequences of all permutations (i.e. no repetition) of the following keywords:

final static synchronized

*** 5. An ϵ-production is a rule of shape $X ::= \epsilon$ (for some nonterminal X). A unit production is a rule of shape $X ::= Y$ (for some non-terminals X and Y). Consider the following grammar G with start symbol S:

$$\begin{array}{rcl} S & ::= & aSbb \mid T \\ T & ::= & bTaa \mid S \mid \epsilon \end{array}$$

This grammar has two unit productions $S ::= T$ and $T ::= S$, and it has an epsilon production

> $T ::= \epsilon$.
>
> Give a grammar with *no* unit productions and *no* ϵ-productions for the language $L(G) \setminus \{\epsilon\}$.