# Exercises: LL(1) Parsing

## Notations

Let grammar $G = \langle V, T, P, S \rangle$ where

- $V$ is the set of non-terminals
- $T$ is the set of terminals
- $S \in V$ is the start symbol
- $P$ is the set of derivation rules of the form $X \to \alpha$
  where $X \in V$ and $\alpha \in (V \cup T)^*$ is a sequence of symbols from $V \cup T$. Empty sequence is denoted by $\epsilon$.

Recall the following definitions:

- $\text{Nullable}(X) = \text{true}$ if and only if $X \to^* \epsilon$
- $\text{First}(t) = \{t\}$
- $\text{First}(X) = \{t \mid X \to^* t\alpha\}$
- $\text{First}(\alpha) = \{t \mid \alpha \to^* t\beta\}$
- $\text{Follow}(X) = \{t \mid S \to^* \alpha X t \beta\}$

where $t \in T$, $X \in V$, $\alpha, \beta \in (T \cup V)^*$ and $\to^*$ denotes a sequence of derivation steps using the rules in $R$.

A parsing table denoted by $\text{Table}[A, t]$ is defined for every $A \in V$ and $t \in T$. It can be constructed as follows.

For every derivation rule $A \to \alpha$,
  for every $t \in \text{First}(\alpha)$, add $\alpha$ to $\text{Table}[A, t]$
  if $\text{Nullable}(\alpha)$ then
    for every $t \in \text{Follow}(A)$, add $\alpha$ to $\text{Table}[A, t]$

Table cells that do not contain any entries denote parse errors. Table cells that contain more than one (distinct) entry are LL(1) conflicts.

# Exercises

For each of the following grammars,

- Compute Nullable, First, Follow sets.
- Fill in the LL(1) parsing table.
- Is the grammar in LL(1)? Justify your answer.
- If not, is there an LL(1) grammar that accepts the same language? Justify your answer.

$G_1$: 
$$\begin{array}{lcl} S & \rightarrow & XY \mid YX \\ X & \rightarrow & ab \\ Y & \rightarrow & bc \end{array}$$

Non-terminals: $S\,X\,Y$
Terminals: $a\,b\,c$

$G_2$: 
$$\begin{array}{lcl} S & \rightarrow & AB\$ \\ A & \rightarrow & a \mid \epsilon \\ B & \rightarrow & b \end{array}$$

Non-terminals: $S\,A\,B$
Terminals: $a\,b\,\$$

$G_3$: 
$$\begin{array}{lcl} A & \rightarrow & BaC \mid Bad \\ B & \rightarrow & a \mid \epsilon \\ C & \rightarrow & D \mid b \\ D & \rightarrow & Cc \end{array}$$

Non-terminals: $A\,B\,C\,D$
Terminals: $a\,b\,c\,d$

$G_4$: 
$$\begin{array}{lcl} Z & \rightarrow & d \\ Y & \rightarrow & \epsilon \\ X & \rightarrow & Y \\ Z & \rightarrow & XYZ \\ Y & \rightarrow & c \\ X & \rightarrow & a \end{array}$$

Non-terminals: $X\,Y\,Z$
Terminals: $a\,c\,d$