Assignment 2
Parsing and Dead Code Elimination

15-411: Compiler Design
Rob Arnold (`rdarnold@andrew`) and Eugene Marinelli (`emarinel@andrew`)

Due: Tuesday, September 23, 2008 (1:30 pm)

Reminder: Assignments are individual assignments, not done in pairs. The work must be all your own.

You may hand in a handwritten solution or a printout of a typeset solution at the beginning of lecture on Tuesday, September 23. Please read the late policy for written assignments on the course web page. If you decide not to typeset your answers, make sure the text and pictures are legible and clear.

Problem 1

[15 points]

Consider the following grammar $\mathcal{G}$ for a dialect of English (apparently spoken in Buffalo, NY):

$$
\begin{aligned}
S &\rightarrow NP\ VP \\
S &\rightarrow Imp \\
NP &\rightarrow N \\
NP &\rightarrow N\ Rel \\
VP &\rightarrow V \\
VP &\rightarrow V\ NP \\
Imp &\rightarrow VP \\
Rel &\rightarrow NP\ V \\
N &\rightarrow \mathsf{buffalo} \\
V &\rightarrow \mathsf{buffalo}
\end{aligned}
$$

It might help you to know the conventions $S =$ "sentence", $NP =$ "noun phrase", $VP =$ "verb phrase", Imp = "imperative", $Rel =$ "relative clause", $N =$ "noun", $V =$ "verb". You may also examine this excerpt from the *The American Heritage® Dictionary of the English Language, Fourth Edition:*

buf·fa·lo
n. *pl.* **buffalo** or **buf·fa·loes** or **buf·fa·los**

1. (a) Any of several oxlike Old World mammals of the family Bovidae, such as the water buffalo and African buffalo.
   (b) The North American bison, Bison bison.
2. The buffalo fish.

tr.v. **buf·fa·loed**, **buf·fa·lo·ing**, **buf·fa·loes**

1. To intimidate, as by a display of confidence or authority: "The board couldn't buffalo the federal courts as it had the Comptroller" (American Banker).
2. To deceive; hoodwink: "Too often... job seekers have buffaloed lenders as to their competency and training" (H. Jane Lehman).
3. To confuse; bewilder.

(a) Derive "buffalo buffalo buffalo buffalo buffalo" from the start symbol S.

(b) Show that $\mathcal{G}$ is not SLR by finding a shift/reduce or reduce/reduce conflict.

(c) Can you find a different grammar that is SLR and that accepts the same language (i.e., the same set of strings) as $\mathcal{G}$?

Problem 2

[20 points]

Consider the following grammar $\mathcal{B}$ for an obfuscated programming language.

$$
\begin{array}{lcl}
P & \rightarrow & A\ \$ \\
A & \rightarrow & [\ A\ ]\ A \\
A & \rightarrow & \epsilon \\
A & \rightarrow & >\ A \\
A & \rightarrow & <\ A \\
A & \rightarrow & +\ A \\
A & \rightarrow & -\ A \\
A & \rightarrow & .\ A \\
A & \rightarrow & ;\ A
\end{array}
$$

(a) What are the FIRST and FOLLOW sets of A?

(b) Construct a predictive parsing table for $\mathcal{B}$ similar to Appel figure 3.12. Is $\mathcal{B}$ LL(1)?

Problem 3

[25 points]

```
total :
    sum ← 0
    i ← 0
loop :
    size ← length(list)
    if i ≥ size goto end
    e ← nth(list, i)
    j ← i + 1
    f ← nth(list, j)
    sum ← sum + e
    i ← i + 1
    goto loop
end :
    return sum
```

(a) Assuming that function calls have the general form $l : x \leftarrow f(a_1, \ldots, a_n)$, give new rules to define the $\mathsf{def}(l, x)$, $\mathsf{use}(l, x)$ and $\mathsf{succ}(l, l')$ predicates for this new instruction as on page L4.9 of the lectures notes on liveness analysis.

(b) Assuming that function calls always terminate and have no side-effects, give any additional rules you might need to specify $\mathsf{nec}(l, x)$ as on page L5.4 of the lecture notes on dataflow analysis. Briefly explain your answer.

(c) Perform liveness and neededness analysis on the program above, constructing a table showing which variables are live, which variables are necessary, and which variables are needed at each line. Assume function calls always terminate and have no side-effects, so you will need the rules from pages L5.4–5, and any additional rules from parts (a) and (b). Indicate which lines of code are "dead" and thus can be eliminated.

(d) Now suppose any function call may have a side-effect. Give any new rules you might need to specify $\mathsf{nec}(l, x)$. Briefly explain your answer.

(c) Repeat part (c), now using rules from L5.4–5, parts (a) and (d).