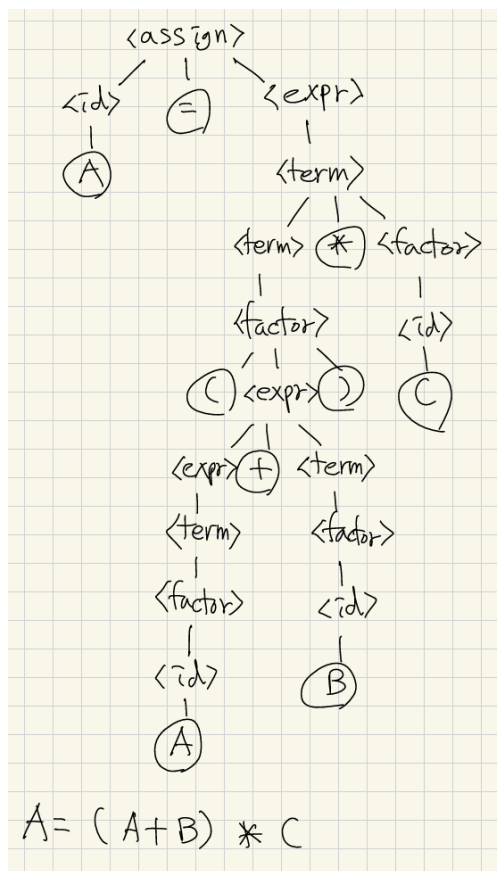


Programming Languages Assignment 1

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Q1. 1) $A = (A + B) * C$

(Please understand that it is difficult to draw parse tree in Word program(.docx file), so I drew parse tree by hand on the I-pad and added it as a picture.)



Leftmost derivation :

$\langle \text{assign} \rangle \rightarrow \langle \text{id} \rangle = \langle \text{expr} \rangle$

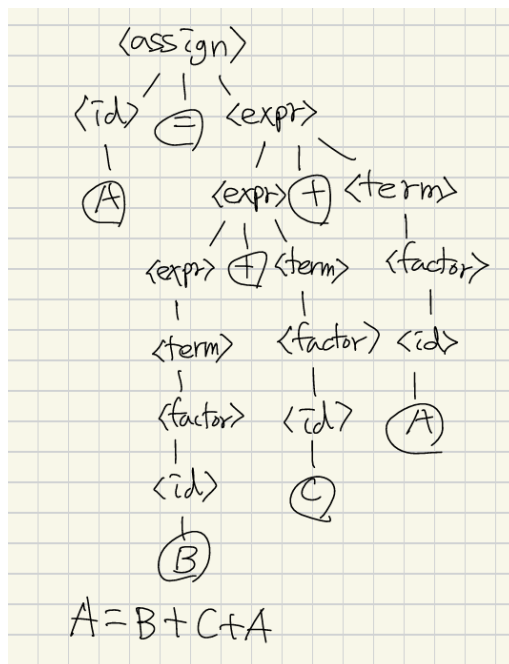
$\rightarrow A = \langle \text{expr} \rangle$

$\rightarrow A = \langle \text{term} \rangle$

$\rightarrow A = \langle \text{term} \rangle * \langle \text{factor} \rangle$

-> $A = \langle \text{factor} \rangle * \langle \text{factor} \rangle$
 -> $A = (\langle \text{expr} \rangle) * \langle \text{factor} \rangle$
 -> $A = (\langle \text{expr} \rangle + \langle \text{term} \rangle) * \langle \text{factor} \rangle$
 -> $A = (\langle \text{term} \rangle + \langle \text{term} \rangle) * \langle \text{factor} \rangle$
 -> $A = (\langle \text{factor} \rangle + \langle \text{term} \rangle) * \langle \text{factor} \rangle$
 -> $A = (\langle \text{id} \rangle + \langle \text{term} \rangle) * \langle \text{factor} \rangle$
 -> $A = (A + \langle \text{term} \rangle) * \langle \text{factor} \rangle$
 -> $A = (A + \langle \text{factor} \rangle) * \langle \text{factor} \rangle$
 -> $A = (A + \langle \text{id} \rangle) * \langle \text{factor} \rangle$
 -> $A = (A + B) * \langle \text{factor} \rangle$
 -> $A = (A + B) * \langle \text{id} \rangle$
 -> $A = (A + B) * C$

2) $A = B + C + A$



Parse tree :

Leftmost derivation :

$\langle \text{assign} \rangle \rightarrow \langle \text{id} \rangle = \langle \text{expr} \rangle$

$\rightarrow A = \langle \text{expr} \rangle$

$\rightarrow A = \langle \text{expr} \rangle + \langle \text{term} \rangle$

$\rightarrow A = \langle \text{expr} \rangle + \langle \text{term} \rangle + \langle \text{term} \rangle$

$\rightarrow A = \langle \text{term} \rangle + \langle \text{term} \rangle + \langle \text{term} \rangle$

$\rightarrow A = \langle \text{factor} \rangle + \langle \text{term} \rangle + \langle \text{term} \rangle$

$\rightarrow A = \langle \text{id} \rangle + \langle \text{term} \rangle + \langle \text{term} \rangle$

$\rightarrow A = B + \langle \text{term} \rangle + \langle \text{term} \rangle$

$\rightarrow A = B + \langle \text{factor} \rangle + \langle \text{term} \rangle$

$\rightarrow A = B + \langle \text{id} \rangle + \langle \text{term} \rangle$

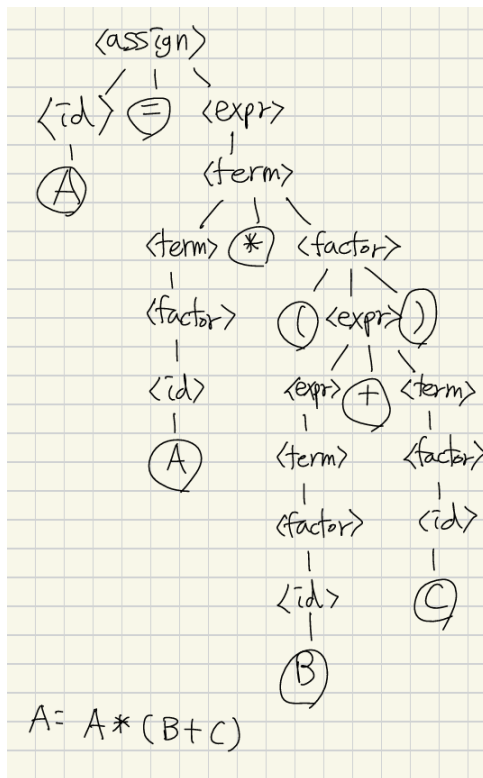
$\rightarrow A = B + C + \langle \text{term} \rangle$

$\rightarrow A = B + C + \langle \text{factor} \rangle$

$\rightarrow A = B + C + \langle \text{id} \rangle$

$\rightarrow A = B + C + A$

3) $A = A * (B + C)$



Parse tree :

Leftmost derivation :

$\langle \text{assign} \rangle \rightarrow \langle \text{id} \rangle = \langle \text{expr} \rangle$

$\rightarrow A = \langle \text{expr} \rangle$

$\rightarrow A = \langle \text{term} \rangle$

$\rightarrow A = \langle \text{term} \rangle * \langle \text{factor} \rangle$

$\rightarrow A = \langle \text{factor} \rangle * \langle \text{factor} \rangle$

$\rightarrow A = \langle \text{id} \rangle * \langle \text{factor} \rangle$

$\rightarrow A = A * \langle \text{factor} \rangle$

$\rightarrow A = A * (\langle \text{expr} \rangle)$

$\rightarrow A = A * (\langle \text{expr} \rangle + \langle \text{term} \rangle)$

$\rightarrow A = A * (\langle \text{term} \rangle + \langle \text{term} \rangle)$

$\rightarrow A = A * (\langle \text{factor} \rangle + \langle \text{term} \rangle)$

-> $A = A * (\langle id \rangle + \langle term \rangle)$

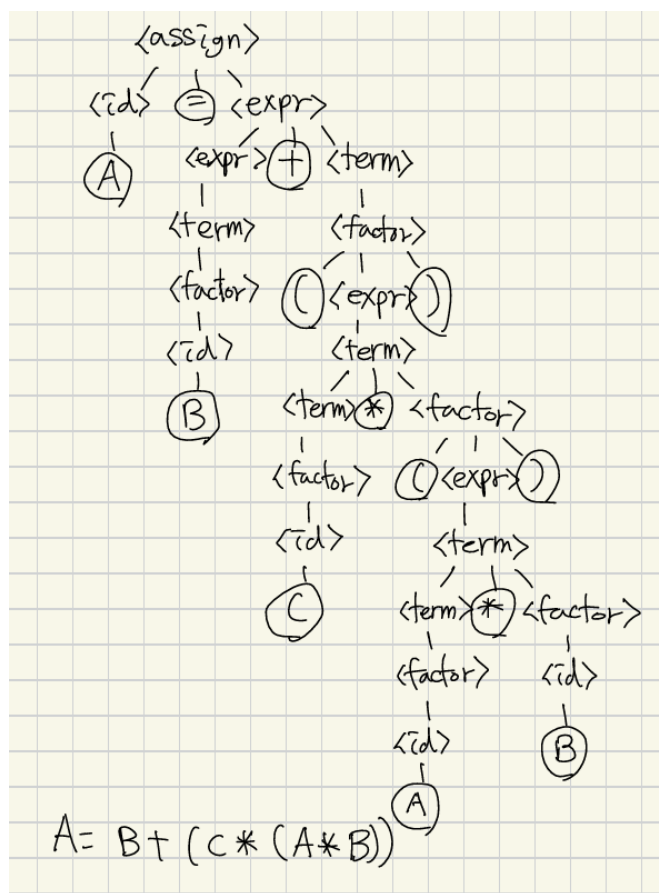
-> $A = A * (B + \langle term \rangle)$

-> $A = A * (B + \langle factor \rangle)$

-> $A = A * (B + \langle id \rangle)$

-> $A = A * (B + C)$

4) $A = B + (C * (A * B))$



Parse tree :

Leftmost derivation :

$\langle assign \rangle \rightarrow \langle id \rangle = \langle expr \rangle$

-> $A = \langle expr \rangle$

-> $A = \langle expr \rangle + \langle term \rangle$

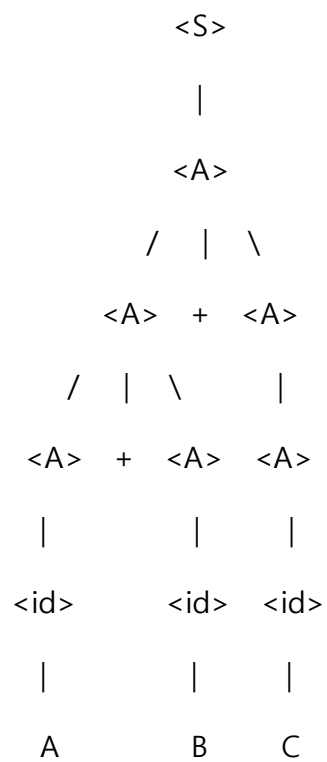
$\rightarrow A = \langle \text{term} \rangle + \langle \text{term} \rangle$
 $\rightarrow A = \langle \text{factor} \rangle + \langle \text{term} \rangle$
 $\rightarrow A = \langle \text{id} \rangle + \langle \text{term} \rangle$
 $\rightarrow A = B + \langle \text{term} \rangle$
 $\rightarrow A = B + \langle \text{factor} \rangle$
 $\rightarrow A = B + (\langle \text{expr} \rangle)$
 $\rightarrow A = B + (\langle \text{term} \rangle)$
 $\rightarrow A = B + (\langle \text{term} \rangle * \langle \text{factor} \rangle)$
 $\rightarrow A = B + (\langle \text{factor} \rangle * \langle \text{factor} \rangle)$
 $\rightarrow A = B + (\langle \text{id} \rangle * \langle \text{factor} \rangle)$
 $\rightarrow A = B + (C * \langle \text{factor} \rangle)$
 $\rightarrow A = B + (C * (\langle \text{expr} \rangle))$
 $\rightarrow A = B + (C * (\langle \text{term} \rangle))$
 $\rightarrow A = B + (C * (\langle \text{term} \rangle * \langle \text{factor} \rangle))$
 $\rightarrow A = B + (C * (\langle \text{factor} \rangle * \langle \text{factor} \rangle))$
 $\rightarrow A = B + (C * (\langle \text{id} \rangle * \langle \text{factor} \rangle))$
 $\rightarrow A = B + (C * (A * \langle \text{factor} \rangle))$
 $\rightarrow A = B + (C * (A * \langle \text{id} \rangle))$
 $\rightarrow A = B + (C * (A * B))$

Q2.

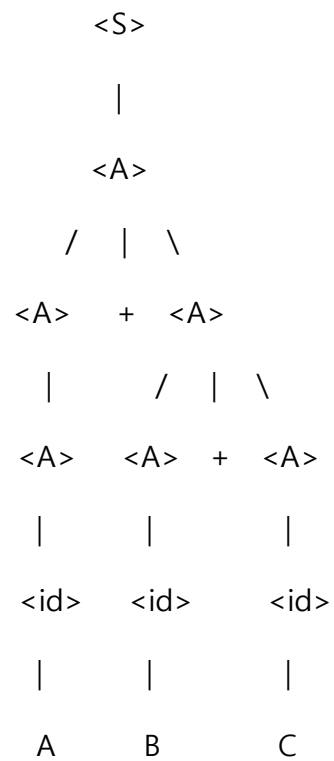
Assume that "A + B + C"

To prove that BNF grammar in Q2 is ambiguous, I should show that there are two or more parse trees for this grammar.

Parse tree 1)



Parse tree 2)



Thus, both Parse trees result in the same final expression "A + B + C". But, the difference in parse tree structures means that the grammar does not enforce a unique way of parsing. In other words, BNF grammar in Q2 is ambiguous.

Q3.

The grammar modified by adding unary minus (-) operator and power (^) operator that have right associativity is as follows.

<Original grammar>

$\langle \text{assign} \rangle \rightarrow \langle \text{id} \rangle = \langle \text{expr} \rangle$

$\langle \text{id} \rangle \rightarrow A \mid B \mid C$

$\langle \text{expr} \rangle \rightarrow \langle \text{expr} \rangle + \langle \text{term} \rangle \mid \langle \text{term} \rangle$

$\langle \text{term} \rangle \rightarrow \langle \text{term} \rangle * \langle \text{factor} \rangle \mid \langle \text{factor} \rangle$

$\langle \text{factor} \rangle \rightarrow (\langle \text{expr} \rangle) \mid \langle \text{id} \rangle$

<Modified grammar>

$\langle \text{assign} \rangle \rightarrow \langle \text{id} \rangle = \langle \text{expr} \rangle$

$\langle \text{id} \rangle \rightarrow A \mid B \mid C$

$\langle \text{expr} \rangle \rightarrow \langle \text{expr} \rangle + \langle \text{term} \rangle \mid \langle \text{term} \rangle$

$\langle \text{term} \rangle \rightarrow \langle \text{term} \rangle * \langle \text{power} \rangle \mid \langle \text{power} \rangle$

$\langle \text{power} \rangle \rightarrow \langle \text{unary} \rangle ^ \langle \text{power} \rangle \mid \langle \text{unary} \rangle$

$\langle \text{unary} \rangle \rightarrow - \langle \text{unary} \rangle \mid \langle \text{factor} \rangle$

$\langle \text{factor} \rangle \rightarrow (\langle \text{expr} \rangle) \mid \langle \text{id} \rangle$