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INF 5110: Compiler construction

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Topic: Context free grammars

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This exercise set covers more than one lecture. It's about grammars, and partly for the lectures about *parsing*. We might not be able to cover it within 2 hours.

Exercise 1 (First- and follow sets) Compute the *First* and *Follow*-sets for the grammar from [1, Figure 4.4, page 160]. See also Figure 1.

$$
\begin{array}{rcl}
exp & \rightarrow & term\ exp' \\
exp' & \rightarrow & addop\ term\ exp' \ \mid\ \boldsymbol{\epsilon} \\
addop & \rightarrow & + \ \mid\ - \\
term & \rightarrow & factor\ term' \\
term' & \rightarrow & mulop\ factor\ term' \ \mid\ \boldsymbol{\epsilon} \\
mulop & \rightarrow & * \\
factor & \rightarrow & (\ exp\ ) \ \mid\ \mathbf{n}
\end{array}
$$

Figure 1: Expression grammar (left-recursion removed)

Exercise 2 (Nullable) Describe an algorithm that finds all nullable non-terminals without first finding the first-sets.

Exercise 3 (Associativity and precedence) Take the binary ops $+$, $-$, $*$, $/$ and $\uparrow$. Let's agree also on the following precedences and associativity

op	precedence	associativity
$+, -$	low	left assoc.
$*, /$	higher	left. assoc.
$\uparrow$	highest	right. assoc

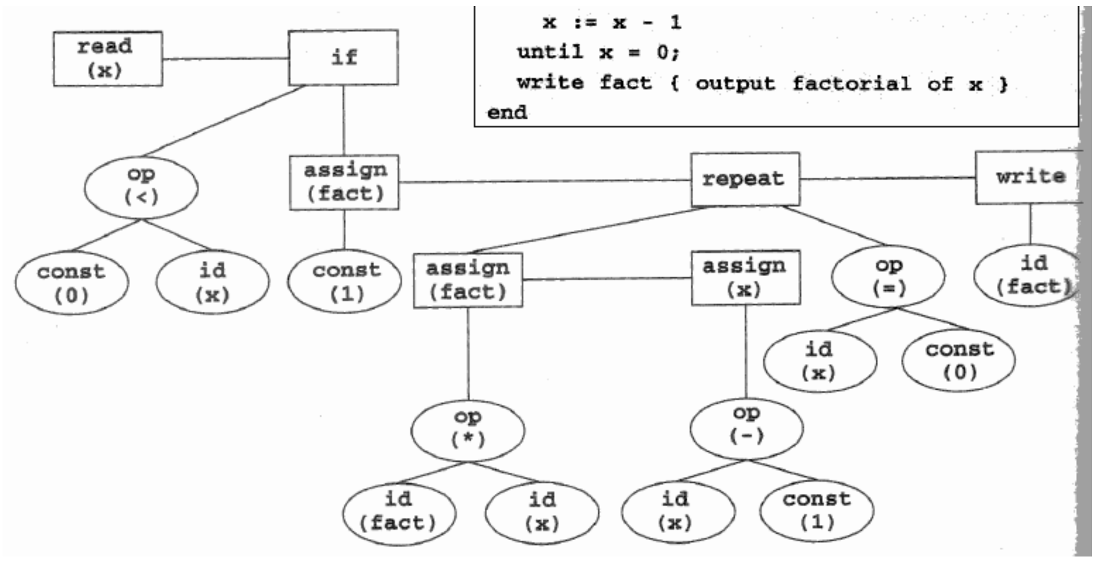
Write an *unambiguous* grammar that captures the given precedences and associativies (of course, directly with a BNF grammar, without allowing yourself specifying those requirements as extra side-conditions).

Exercise 4 (Tiny grammar) [1] discusses various issues with the help of a simple language TINY. The grammar as given by the book is repeated here. For that grammar, answer the following questions:

- Is the grammar *unambiguious?*
- How can we change the grammar, so that TINY allows empty statements?
- How can we arrange it that semicolons are required *in between* statements, not *after* statements?
- What's the precedence and associativity of the different operators?

$$
\begin{array}{rcl}
\textit{program} & \rightarrow & \textit{stmt-seq} \\
\textit{stmt-seq} & \rightarrow & \textit{stmt-seq}\,;\textit{stmt} \;\mid\; \textit{stmt} \\
\textit{stmt} & \rightarrow & \textit{if-stmt} \;\mid\; \textit{repeat-stmt} \;\mid\; \textit{assign-stmt} \\
 & \mid & \textit{read-stmt} \;\mid\; \textit{write-stmt} \\
\textit{if-stmt} & \rightarrow & \textbf{if}\ \textit{expr}\ \textbf{then}\ \textit{stmt}\ \textbf{end} \\
 & \mid & \textbf{if}\ \textit{expr}\ \textbf{then}\ \textit{stmt}\ \textbf{else}\ \textit{stmt}\ \textbf{end} \\
\textit{repeat-stmt} & \rightarrow & \textbf{repeat}\ \textit{stmt-seq}\ \textbf{until}\ \textit{expr} \\
\textit{assign-stmt} & \rightarrow & \textbf{identifier} := \textit{expr} \\
\textit{read-stmt} & \rightarrow & \textbf{read identifier} \\
\textit{write-stmt} & \rightarrow & \textbf{write}\ \textit{expr} \\
\textit{expr} & \rightarrow & \textit{simple-expr comparison-op simple-expr} \;\mid\; \textit{simple-expr} \\
\textit{comparison-op} & \rightarrow & < \;\mid\; = \\
\textit{simple-expr} & \rightarrow & \textit{simple-expr addop term} \;\mid\; \textit{term} \\
\textit{addop} & \rightarrow & + \;\mid\; - \\
\textit{term} & \rightarrow & \textit{term mulop factor} \;\mid\; \textit{factor} \\
\textit{mulop} & \rightarrow & * \;\mid\; / \\
\textit{factor} & \rightarrow & (\,\textit{expr}\,) \;\mid\; \textbf{number} \;\mid\; \textbf{identifier}
\end{array}
$$

Exercise 5 (AST) [1] gave some illustration and proposal for an AST data structure for TINY:



The tree representation corresponds to the following piece of source code.

Listing 1: Sample TINY program

```
read x; { input as integer }
if 0 < x then { don't compute if x <= 0 }
  fact := 1;
  repeat
```

```
    fact := fact * x;
    x := x -1
  until x = 0;
  write fact   { output factorial of x }
end
```

Design an appropriate AST data structure, using object-oriented structuring. In particular, make use if an appropriately define class *hierarchy* (i.e., use inheritance). This should give a "better-structured" AST data structure compared to [1], where all the nodes of the AST tree are ultimately just "nodes".

References

[1] K. Louden. *Compiler Construction, Principles and Practice.* PWS Publishing, 1997.