Syntax

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1. Objectives & Definitions

- A programming language is a formal notation for describing algorithm by computer using two components:
  - **Syntax**: What does a program look like?
  - **Semantics**: What does a program mean?

- Who must use language definitions?
  - Other language designers
  - Implementers
  - Programmers (the users of the language)

- **Syntax**:
  - It is a set of rules that formally describe the form or structure of the expressions, statements, and program units.
  - Example:
    - The syntax in programming language define the notation used for arithmetic expressions:
      - Infix notation "5 + 6"
      - Prefix notation "+ 5 6"
    - The syntax define the delimiter of a statement: ";"

- **Semantics**:
  - It is the meaning of any syntactically valid program written in the language, e.g., expressions, statements, and program units. Note that all syntactically correct programs have valid.

- It is hard to describe the meaning of a language:
  - **Informal description**: describe in English the meaning of a construct.
  - **Formal description**: A mathematical model using formal notation to describe each construct.

- Example:
  - The syntax of a C if statement is:

    If (<expression>) <statement>

    The meaning of this statement form is that the current value of the expression is true, the embedded statement is selected for execution.

  - It would be nice to have a formal description for such construct!!

2. Definitions

- **Syntax:**
  - Any language whether natural (such as English) or artificial (such as Java) is a set of words of characters from some alphabet.
  - A sequence of words is called a sentence (in English) or a statement (in a programming language).
  - The syntax rules of a language specify which sentences are in the language.
  - There are two types of syntax rules:
    - Lexical rules
    - Syntactic rules

3. Lexical Rules

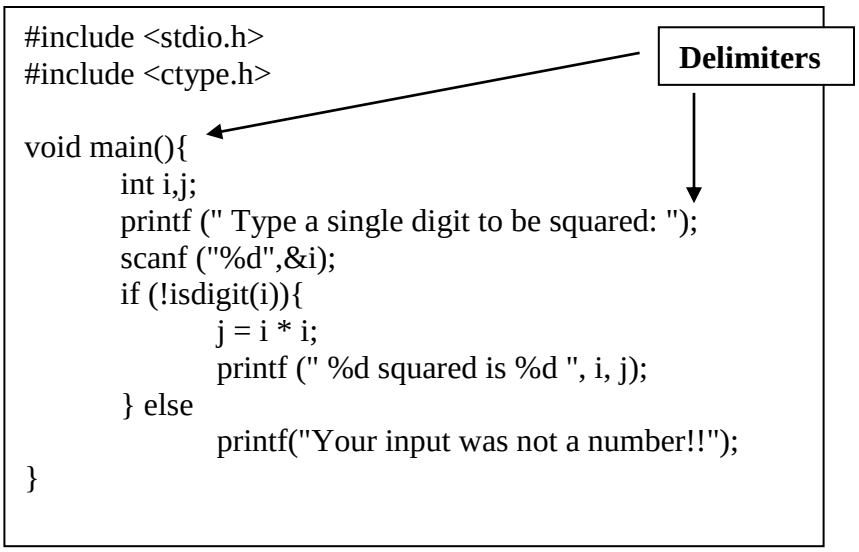
- **Objectives**:
  - It helps the programmer know how to write a syntactically correct program.
  - Compiler developers use syntax rules to write syntax analyzer or parser to check the validity of a program.
  - Availability of tools to generate lexical and syntax analyzers: Lex and Yacc.

- **Alphabet**:
  - They specify the set of characters that constitute the alphabet of the language.
  - An alphabet (or vocabulary), V, is a finite non-empty set of symbols.
  - Example:
    - <> and # is valid operator in Pascal and not in C.
- **Words**:
  - The way the characters are combined to form a word.
  - A word over V is a finite string of symbols from V.
  - V * is the set of all the words over V. V * is called the **closure** of V.
  - Example:
    - Java and java are two different variables in C language.
- **Languages**:
  - A language, L, is any subset of V *.
  - A set of rules for forming the words in a language is called a **grammar**.

- **Syntactic Elements of a language**:
  - Character set
  - Identifiers
  - Operator symbols (e.g., ==, !=, #)
  - Reserved Keywords (e.g., class, For, procedure)
  - Comments
  - Blanks (should not have a space between += in java)
  - Delimiters and Brackets:
    - ";" marks the end of a statement in C and Java.
    - "begin … end" marks the beginning and the end of a block of code in Ada and Pascal
    - "{ …}" marks the beginning and the end of a block in Java and C.

  - Expressions
  - Statements

- **Example**: A C Program




```
#include <stdio.h>
#include <ctype.h>

void main(){
        int i,j;
        printf (" Type a single digit to be squared: ");
        scanf ("%d",&i);
        if (!isdigit(i)){
                j = i * i;
                printf (" %d squared is %d ", i, j);
        } else
                printf("Your input was not a number!!");
}
```

4. BNF: Formal Syntactic rules

- A little of **history**:
  - Fortran was defined using informal definitions (English Description)
  - Algol 60 was defined by a formal definition (a context free grammar) developed by John Backus.
- **Meta-Language**:
  - It is a language that is used to describe other languages.
  - They may be notational or graphical
  - Example: **B**ackus-**N**aur **F**orm (BNF)

- **BNF Definition**:

  - A formal definition defined by John Bachus and Peter Naur to express Algol syntax.

  - A set of nonterminals, terminals, and production rules which define legal sentences in a language.

  - A BNF Rule:

    <program> ::= {<stmt>*}

    reads as

    program is defined as zero or several statements.

Another example: Description of while statement

<while_stmt> ::= while (<logic_expr>) <stmt>

- **Terminals**:
  - The primitive tokens of the language ("a", "+", "begin",...)
- **Nonterminals**:
  - Enclosed in "<" and ">", such as <prog>
- **Production rules**:
  - A single nonterminal, followed by "::=", followed by a sequence of terminals and nonterminals.
- **MetaSymbols**:
  - "+": One of more occurrences of the previous element.
  - "*": Zero or more occurrences of the previous element.
  - "|": means "or"

- **Example**:
  - Terminals:

    "a" "b" "c" "+" "-" ";" "begin" "end"

  - Nonterminals

    <prog> <stmt_list> <stmt> <var> <exp>

- Production rules:

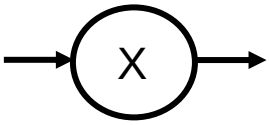
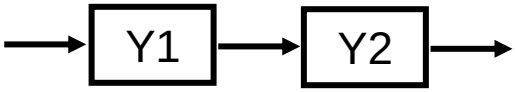
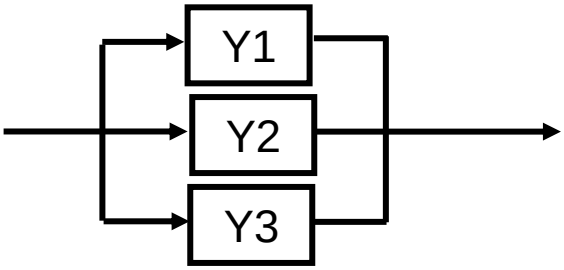
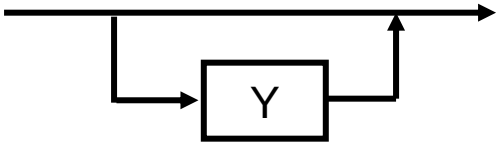
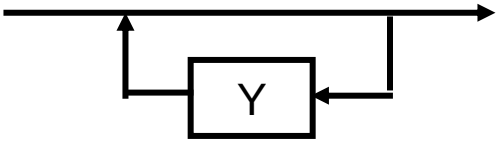
  <prog> ::= "begin" <stmt_list> "end"
  <stmt_list> ::= <stmt>
  <stmt_list> ::= <stmt> ";" <stmt_list>
  <stmt> ::= <var> ":=" <exp>
  <var> ::= "a"
  <var> ::= "b"
  <var> ::= "c"
  <exp> ::= <var> "+" <var>
  <exp> ::= <var> "-" <var>
  <exp> ::= <var>

5. Syntax **Diagrams**

- A pictorial representation of the syntax of a language.

- They are equivalent to BNF:
  - Put the terminals in circles or ellipses
  - Put the nonterminals in rectangles
  - Connect with lines with arrowheads

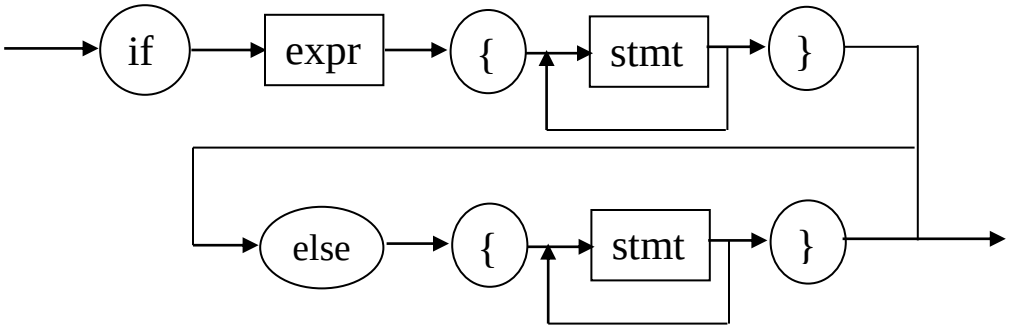
- Direct mapping to/from EBNF:

Nonterminal	Y	
Terminal	X	
Sequence	Y1 Y2	
Alternation	Y1| Y2| Y3	
Optional	[Y]	
Repetition	{Y}	

- Example: Conditional Statement:

  BNF:

  <cond> ::= if <expr> {<stmt>+} |
  if <expr> {<stmt>+} else {<stmt>+}



6. EBNF: Extended BNF

- EBNF extends BNF syntax to make grammars more readable.

- EBNF Symbols:

  - Replace ::= with $\rightarrow$
  - No < > around nonterminals
  - Enclose terminals in single quotes
  - Optional constructs in [ ]
  - Repetitions in { } (or use …)
  - Grouping with ( )

- Sequence:

if → "if " test "then" stmt

- Optional: “[ ]”

  if → "if " test "then" stmt ["else" stmt]

- Alternative: “|”

  number → integer | real

- Group: “( )”

  exp → var | (var "+" var)

- Repetition: “{ }”

  ident_list → ident { "," ident}

7. Example:

- BNF

  <exp> ::= <exp>+<term> | <exp>-<term> | <term>
  <term> ::= <term>*<factor> | <term>/<factor> | <factor>
  <factor> ::= (<exp>) | <identifier>

- EBNF

  exp → term { (‘+’ | ’-’) term }
  term → factor { (‘*’ | ‘/’) factor }
  factor → ‘(‘ exp ‘)’ | identifier

8. BNF Statement Derivation

- Statements are generated using a sequence of applications of syntactic rules.

- A derivation is the process that allows the generation of a statement.

- Example:

  - A Simple assignment Statements

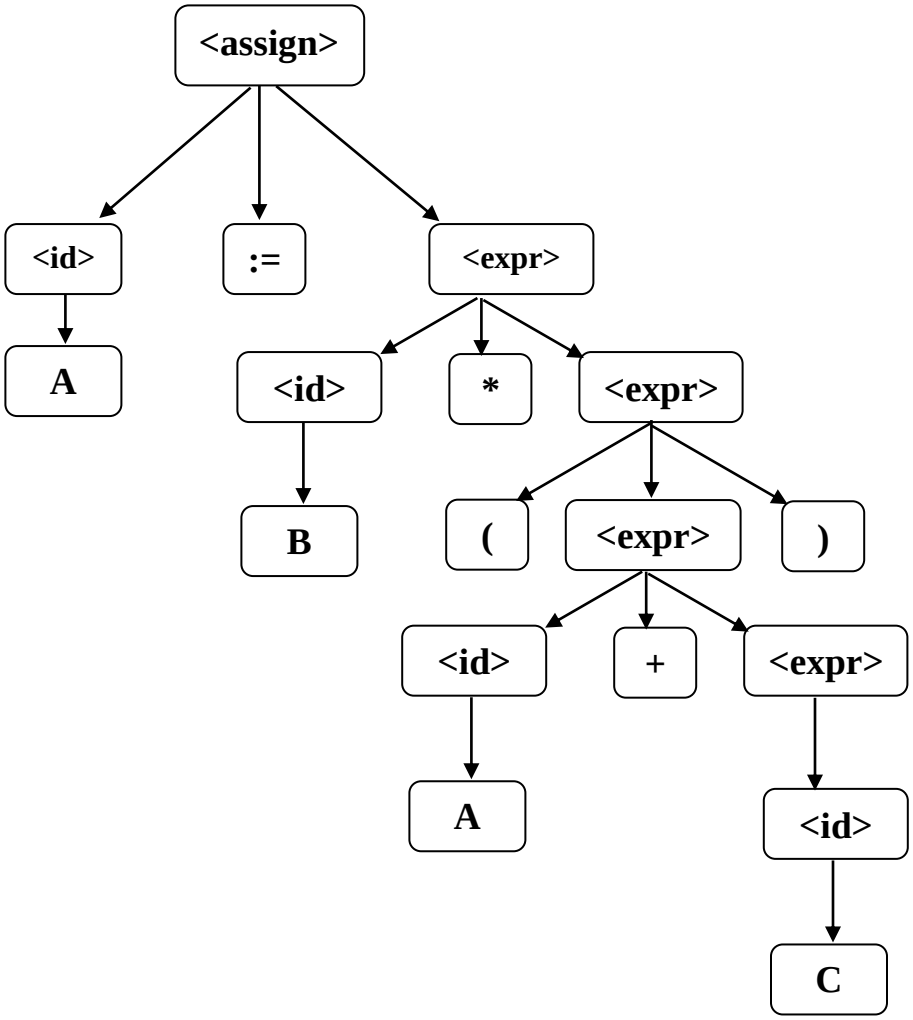
$$
\begin{array}{lcl}
\text{assign} & \rightarrow & \text{id := expr} \\
\text{id} & \rightarrow & \text{A | B | C} \\
\text{expr} & \rightarrow & \text{id + expr} \\
 & & \quad \text{| id * expr} \\
 & & \quad \text{| (expr)} \\
 & & \text{| id}
\end{array}
$$

  - Derivation: A := B * (A + C)

$$
\begin{array}{ll}
\text{assign} & \Rightarrow \text{id := expr} \\
 & \Rightarrow \text{A := expr} \\
 & \Rightarrow \text{A := id * expr} \\
 & \Rightarrow \text{A := B * expr} \\
 & \Rightarrow \text{A := B * (expr)} \\
 & \Rightarrow \text{A := B * (id + expr)} \\
 & \Rightarrow \text{A := B * (A + expr)} \\
 & \Rightarrow \text{A := B * (A + id)} \\
 & \Rightarrow \text{A := B * (A + C)}
\end{array}
$$

9. Parse Trees

- Alternative representation for a derivation
- Example: A parse tree for the previous example



10. Ambiguity

- A Syntax definition that generates a statement for which there are two or more distinct parse trees or derivations is said to be **ambiguous**.
- Example: A classical example of the 'Dangling else":

```
if (x <0)
if (y<0)
y = y-1;
else
y = 0;
```

- Which if statement has the "else" part?

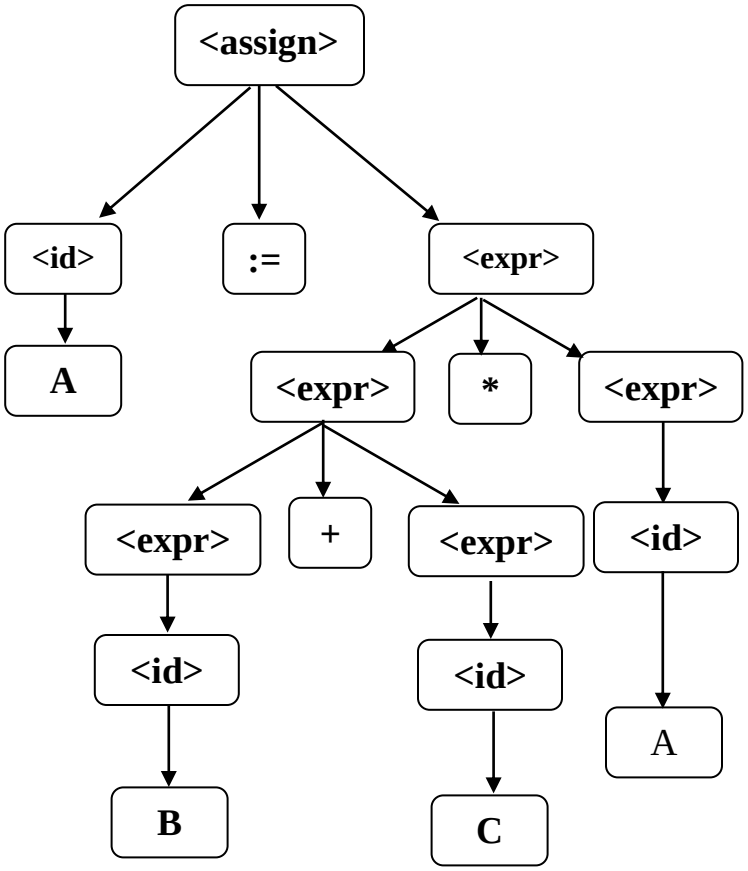
if (x <0)
  if (y<0)
  y = y-1;
else
  y = 0;
	if (x <0)
	  if (y<0)
	  y = y-1;
	  else
	  y = 0;

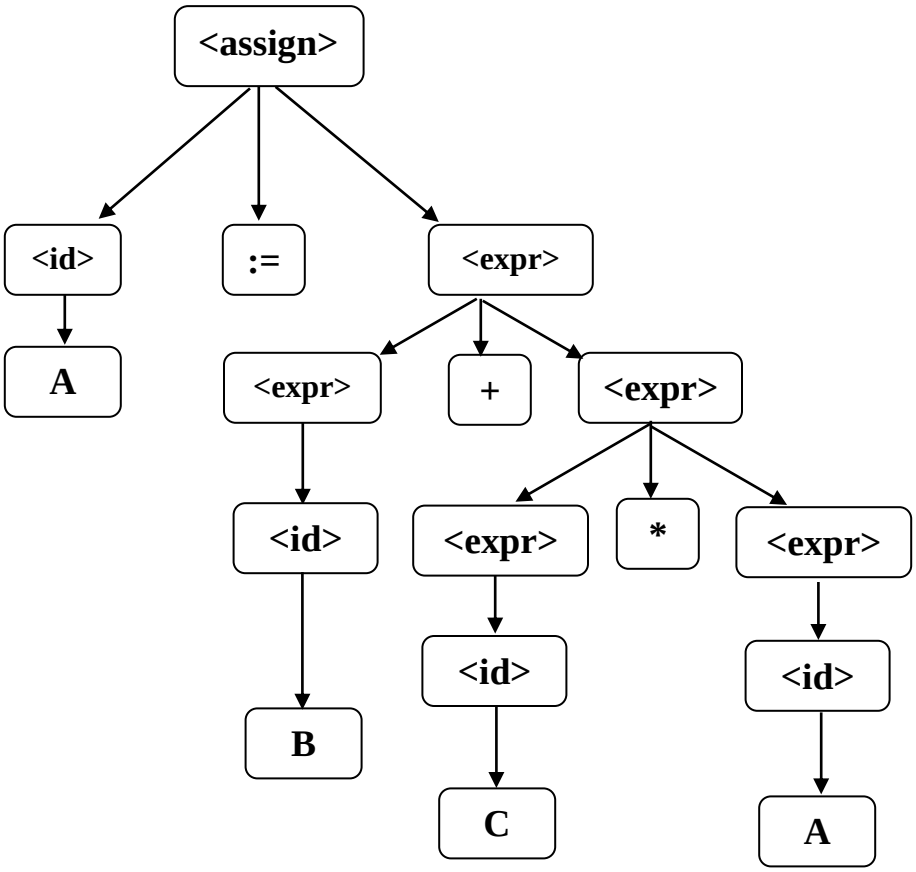
- Example:
  - Another Simple assignment Statements

<assign> → <id> := <expr>
<id> → A | B | C
<expr> → <expr> + <expr>
| <expr> * <expr>
| (<expr>)
| <id>

  - What is the difference between this syntax and the previous one?

- Two parse trees for A := B + C * A




<assign>
<id>
:=
<expr>
A
<expr>
+
<expr>
<id>
<expr>
*
<expr>
B
<id>
<id>
C
A

11. Abstract Syntax-Concrete Syntax

- **Definition**: Two syntax rules have the same **abstract syntax** if they only differ at the lexical level or **concrete syntax**.
- **Readability might be affected**: Is it better to use != or ≠

- Example: For Loop construct:
  - Ada:

```
FOR counter IN lowbound..highbound
LOOP
    Sequence of statements;
END LOOP;
```

  - C:

```
For (i=0;i<cond;cond){
    Sequence of statements;
}
```