BNF Fundamentals

<LHS> → <RHS>
LHS:abstraction being defined
RHS:definition
"→" means "can have the form"
::= is used for →
<assign> → <var> = <expression>,this is a rule.var and expression be defined.
-These abstractions are called variables or nonterminals
-lexemes and tokens are the terminals
<ident_list> → identifier | identifier, <ident_list>
<if_stmt> → if <logic_expr> then <stmt>
A **rule** has a left-hand side (LHS), which is a nonterminal, and a right-hand side (RHS), which is a string of terminals and/or nonterminals.

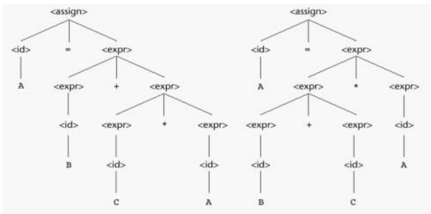
<LHS> → <RHS>

Grammar: a finite non-empty set of rules.
Example:
Mary greets Alfred
<sentence> ::= <subject><predicate>
<subject> ::= <noun>
<predicate> ::= <verb><object>
<verb> ::= greets
<object> ::= <noun>
<noun> ::= Mary | John | Alfred

Grammars and Derivations

-The sentences of the language are generated through a sequence of applications of the rules, starting from the special nonterminal called *start symbol*.Such a generation is called a derivation.
If always the leftmost nonterminal is replaced, then it is called leftmost derivation.
A grammar is ***ambiguous*** if and only if it generates a sentential form that has two or more distinct parse trees.
<assign> ::= <id> = <expr>
<id> ::= A | B | C
<expr> ::= <expr> + <expr>
| <expr> * <expr>
| (<expr>)
| <id>

Parse trees of **A = B + C * A**



<expr> -> <expr> + <expr> | const (ambiguous)
<expr> -> <expr> + const | const (unambiguous)
-In a BNF rule, if the LHS appears at the beginning of the RHS, the rule is said to be left recursive. Left recursion specifies left associativity.
<expr> ::= <expr> + <term>
| <term>
-most of the languages exponential is defined as a right associative operation
<factor> ::= <expr> ** <factor>
| <expr>
<expr> ::= (<expr>)
| <id>
Extended BNF: Optional parts are placed in brackets [ ].
Repetitions (0 or more) are placed inside braces { }.
Alternative parts of RHSs are placed inside parentheses and separated via vertical bars.

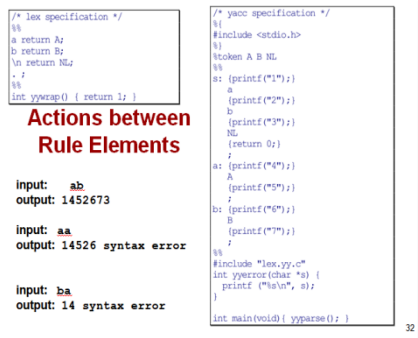
Designing Patterns(Lex)

[abc] matches **a, b or c**
[a-f] matches **a, b, c, d, e, or f**
[0-9] matches any digit
X+ matches one or more of **X**
X* matches zero or more of **X**
[0-9]+ matches any integer
(…) grouping an expression into a single unit
(a|b|c)* is equivalent to **[a-c]***
X? X is optional (0 or 1 occurrence)
if(def)? matches **if** or **ifdef** (equivalent to **if|ifdef**)
[A-Za-z] matches any alphabetical character
. matches any character except newline character
\. matches the **.** character
\n matches the newline character
\t matches the tab character
**** matches the **** character
[\t] matches either a space or tab character
[^a-d] matches any character other than **a**,**b**,**c** and **d**
Real numbers
[0-9]*(\.)?[0-9]+
To include an optional preceding sign:
[+-]?[0-9]*(\.)?[0-9]+
Integer or floating point number
[0-9]+(\.[0-9]+)?
Integer, floating point or scientific notation.
[+-]?[0-9]+(\.[0-9]+)?([eE][+-]?[0-9]+)?
-**Lex** builds the **yylex()** function that is called, and will do all of the work for you.
-**Lex** also provides a count **yyleng** of the number of characters matched**.**
-yywrap is called whenever lex reaches an end-of-file
-Lex is a tool for writing lexical analyzers**.**
-Yacc is a tool for constructing parsers.

Yacc

-Yacc stands for **y**et **a**nother **c**ompiler to **c**ompiler. Reads a specification file that codifies the grammar of a language and generates a parsing routine.
-Yacc specification describes a Context Free Grammar (CFG), that can be used to generate a parser.
Elements of a CFG:
1. Terminals: tokens and literal characters,
2. Variables (nonterminals): syntactical elements,
3. Production rules, and
4. Start rule.

-Format of a **yacc** specification file:
declarations
%%
grammar rules and associated actions
%%
C programs
-Declarations
%token: declare names of tokens
%left: define left-associative operators
%right: define right-associative operators
%nonassoc: define operators that may not associate with themselves
%type: declare the type of variables
%union: declare multiple data types for semantic values
%start: declare the start symbol (default is the first variable in rules)
%prec: assign precedence to a rule
%{ C declarations directly copied to the resulting C program **%}**
$$: left-hand side
$1: first item in the right-hand side
$n: n[th] item in the right-hand side
-Yacc provides a special symbol for handling errors. The symbol is called error and it should appear within a grammar-rule. -**yylex()** function returns an integer, the token number, representing the kind of token read. If there is a value associated with that token, it should be assigned to the external variable **yylval.**



Scheme

```
1.(DEFINE (compare x y)
  (COND
   ((> x y) "x is greater than y")
   ((< x y) "y is greater than x")
   (ELSE "x and y are equal") ) )
2.(CONS 'A '(B C)) returns (A B C)
3.(LIST 'apple 'orange 'grape) return (apple orange grape)
4.(CAR '(A B C)) yields A
5.(CAR '((A B) C D)) yields (A B)
6.(CDR '(A B C)) yields (B C)
7.(CDR '((A B) C D)) yields (C D)
8.(LIST? '()) yields #T
9.(NULL? '(())) yields #F
10.(DEFINE (member atm lis)
     (COND
      ((NULL? lis) #F)
      ((EQ? atm (CAR lis)) #T)
      ((ELSE (member atm (CDR lis)))))
11.(DEFINE (second a_list) (CAR (CDR a_list)))
   (second '(A B C))  = returns B
12.(CADDAR x)   = (CAR (CDR (CDR (CAR x))))
   (CADDAR '((A B (C) D) E)) = returns (C)
13.(DEFINE (equalsimp lis1 lis2)
     (COND
      ((NULL? lis1) (NULL? lis2))
      ((NULL? lis2) #F)
      ((EQ? (CAR lis1) (CAR lis2))
         (equalsimp(CDR lis1)(CDR lis2)))
      (ELSE #F)))
14.(DEFINE (equal lis1 lis2)
     (COND
      ((NOT (LIST? lis1))(EQ? lis1 lis2))
      ((NOT (LIST? lis2)) #F)
      ((NULL? lis1) (NULL? lis2))
      ((NULL? lis2) #F)
      ((equal (CAR lis1) (CAR lis2))
          (equal (CDR lis1) (CDR lis2)))
      (ELSE #F)))
15.(DEFINE (append lis1 lis2)
     (COND
      ((NULL? lis1) lis2)
      (ELSE (CONS (CAR lis1)
              (append (CDR lis1) lis2)))))
  * (append '(A B) '(C D R)) returns (A B C D R)
  *(append '((A B) C) '(D (E F))) returns ((A B) C D (E F))
16.(DEFINE (quadratic_roots a b c)
     (LET (
       (root_part_over_2a
          (/ (SQRT (- (* b b) (* 4 a c)))(* 2 a)))
       (minus_b_over_2a (/ (- 0 b) (* 2 a)))
     (DISPLAY (+ minus_b_over_2a root_part_over_2a))
     (NEWLINE)
     (DISPLAY (- minus_b_over_2a root_part_over_2a)))
17.Original: (DEFINE (factorial n)
               (IF (= n 0)
                  1
                  (* n (factorial (- n 1))) ))
Tail Recursive: (DEFINE (facthelper n factpartial)
                  (IF (= n 0)
                     factpartial
                     facthelper((- n 1) (* n factpartial)))))
                (DEFINE (factorial n)
                  (facthelper n 1))
18.(DEFINE (compose f g) (LAMBDA (x) (f (g x))))
    ((compose CAR CDR) '((a b) c d)) yields c
19.(DEFINE (third a_list)
      ((compose CAR (compose CDR CDR)) a_list)) is
equivalent to CADDR
20.(DEFINE (map fun lis)
      (COND
       ((NULL? lis) ())
       (ELSE (CONS (fun (CAR lis))
           (map fun (CDR lis))))))
21.(map (LAMBDA (num) (* num num num)) '(3 4 2 6))
yields (27 64 8 216)
22.((DEFINE (adder lis)
      (COND
       ((NULL? lis) 0)
       (ELSE (EVAL (CONS '+ lis)))))
23.(DEFINE sum
     (lambda (l)
       (if (null? l)
          0
          (+ (car l) (sum (cdr l))))))
24.(DEFINE product
     (lambda (l)
       (if (null? l)
          1
          (* (car l)  (product (cdr l))))))
25.(DEFINE length
     (lambda (l)
       (if (null? l)
          0
          (+ 1 (length (cdr l))))))
26.(DEFINE reverse
      (lambda (l)
        (if (null? l)
           nil
           (append (reverse (cdr l)) (list (car l))))))
27.(DEFINE (third list)
      (caddr list))
   (third '(1 2 3 4 5 6 7)) returns 3
28.(DEFINE a 1)
   (DEFINE b 2)
   (DEFINE c 3)
   (let ((a 2)
         (b (+ a 7))
         (c b))
   (+ a b c)) returns 12
29.(DEFINE (my-func f)
      (lambda (x y) (f (f x y) (f x y))))
   (my-func *) 2 4) returns 64
30.(DEFINE (smallest x y z)
     (min x y z))
```

Subprograms

1.Pass-by-value(In Mode): The value of the actual parameter is used to initialize the corresponding formal parameter.Normally implemented by copying.Can be implemented by transmitting an access path but not recommended.

2.Pass-by-result(Out Mode): No value is transmitted to the subprogram.The corresponding formal parameter acts as a local variable.Its value is transmitted to caller's actual parameter when control is returned to the caller.Require extra storage location and copy operation.

Example: Subprogram sub(x, y) { x <- 3 ; y <-5;}

call:

sub(p, p)

what is the value of p here ? (3 or 5?)

-The values of x and y will be copied back to p. Which ever is assigned last will determine the value of p.

-The order is important.

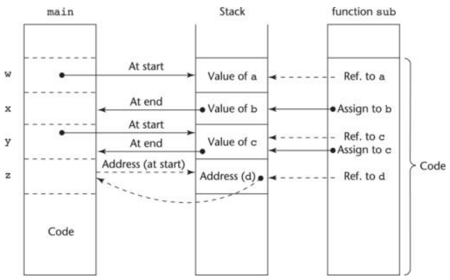
3.Pass-by-value-result(Inout Mode): A combination of pass-by-value and pass-by-result.Formal parameters have local storage.The value of the actual parameter is used to initialize the corresponding formal parameter.

-The formal parameter acts as a local parameter.

-At termination, the value of the formal parameter is copied back.

4.Pass-by-reference(Inout Mode): Pass an access path.Also called pass-by-sharing.Adv:-Passing process is efficient.-No copying.-No duplicated storage.Disadv:-Slower accesses to formal parameters.-Potentials for unwanted side effects(collisions).-Unwanted aliases(access broadened).

5.Pass-by-name(Inout Mode): By textual substitution: Actual parameter is textually substituted for the corresponding formal parameter in all occurrences in the subprogram.Late binding: actual binding to a value or an address is delayed until the formal parameter is assigned or referenced.Allows flexibility in late binding.If the actual parameter is a scalar variable, then it is equivalent to pass-by-reference.If the actual parameter is a constant expression, then it is equivalent to pass-by-value.Adv:-Flexibility.Disadv:-Slow exe.-Difficult to implement.-Confusing.



Function header: **void** sub(**int** a, **int** b, **int** c, **int** d)

Function call in main: sub(w, x, y, z)

(pass w by value, x by result, y by value-result, z by reference)

```
Example:
function sub1() {
  var x;              2:declared in          Passed subprogram S2
  function sub2() {                          Output:
    window.status = x;                       is called by S4
  } // sub2                                  is declared in S1
  function sub3(){                           is passed in S3
    var x;
    x = 3;
    sub4(sub2);    3: passed in
  } // sub3
  function sub4(subx) {
    var x;
    x = 1;
    subx();           1:called by
  } // sub4
  x = 2;
  sub3();
} // sub1
```

-An *overloaded subprogram* is one that has the same name as another subprogram in the same referencing environment.

-A *generic* or *polymorphic subprogram* takes parameters of different types on different activations.

-A *coroutine* is a special kind of a subprogram that has multiple entries and controls them itself.*Coroutines call is a resume.*

***Implementing Simple Subprograms**

-Two separate parts: the actual code (constant) and the non-code part (local variables and data that can change).

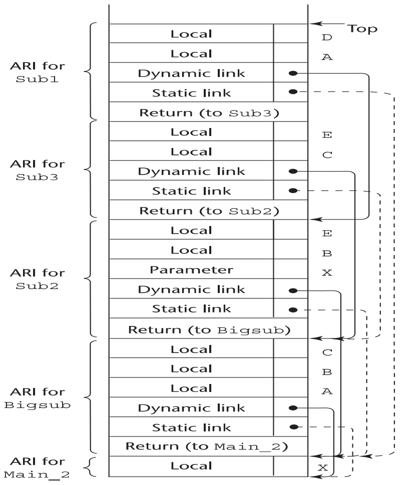
-The format, or layout, of the non-code part of an executing subprogram is called an *activation record.*

-The form of an activation record is static.

-An *activation record instance (ARI)* is a concrete example of an activation record.

```
void fun1(float r) {        void fun2(int x){
int s, t;                   int y;
fun2(s);                    fun3(y);
}                           }
void fun3(int q) {          void main(){
}                           float p;
                            fun1(p);
                            }
```

```
procedure Main_2 is
  X : Integer;
  procedure Bigsub is
    A, B, C : Integer;
    procedure Sub1 is
      A, D : Integer;
      begin -- of Sub1
      A := B + C;  <-----------------------1
    end;  -- of Sub1
    procedure Sub2(X : Integer) is
      B, E : Integer;
      procedure Sub3 is
        C, E : Integer;
        begin -- of Sub3
        Sub1;
        E := B + A:   <--------------------2
        end; -- of Sub3
      begin -- of Sub2
      Sub3;
      A := D + E;  <-----------------------3
      end; -- of Sub2 }
    begin -- of Bigsub
    Sub2(7);
    end; -- of Bigsub
  begin
  Bigsub;
end; of Main_2 }
```



static link parent fonksiyona gider.dynamic link çağrıldığı yere gider.

(CHAIN_OFFSET, LOCAL_OFFSET)

At position 1 in sub1:

A - (0,3)

B - (1,4)

C - (1,5)

At position 2 in sub3:

E - (0,4)

B - (1,4)

A - (2,3)

At position 3 in sub2:

A - (1,3)

D - error

E - (0,5)

Dynamic chain (call chain): The collection of dynamic links in the stack at a given time.

-Local variables can be accessed by their offset from the beginning of the activation record, whose address is in the EP. This offset is called the *local_offset.*

Functional value	
Parameter	n
Dynamic link	
Return address	

Activation record for factorial.

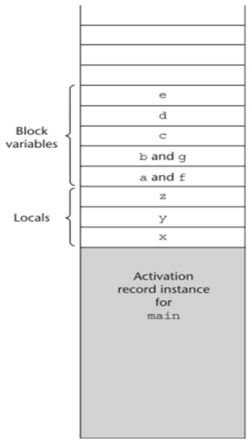
***Implementing Static Scoping**

-A *static chain* is a chain of static links that connects certain activation record instances.

-The *static link* in an activation record instance for subprogram A points to the bottom of one of the activation record instances of A's static parent.

-The static chain from an activation record instance connects it to all of its static ancestors.

```
void main() {
  int x, y, z;
  while ( ... ) {
    int a, b, c;
    ...
    while ( ... ) {
      int d, e;
      ...
    }
  }
  while ( ... ) {
    int f, g;
    ...
  }
  ...
}
```



-S*tatic_depth* is an integer associated with a static scope whose value is the depth of nesting => indicates how deeply it is nested in the outermost scope.

STATIC_DEPTH-> scope iç içe geme sırası. ağaçtaki derinliği.

-The *chain_offset* or *nesting_depth* of a nonlocal reference is the difference between the static_depth of the reference and static_depth of the procedure containing its declaration.

CHAIN_OFFSET-> variablenın declare edildiği yerin ilk tanımlandığı parent scope a olan uzaklığı.

LOCAL_OFFSET-> variablenın ilk olarak tanımladığı fonksiyonun ARI'sindeki alttan yukarıya sırası.0'dan baslayıp.

-A reference to a variable can be represented by the pair: (chain_offset, local_offset), where local_offset is the offset in the activation record of the variable being referenced.

***Implementing Dynamic Scoping**

-*Deep Access*: non-local references are found by searching the activation record instances on the dynamic chain. Length of the chain cannot be statically determined. Ength of the chain cannot be statically determined.

-Sh*allow Access*: put locals in a central place.

One stack for each variable name.

Central table with an entry for each variable name.

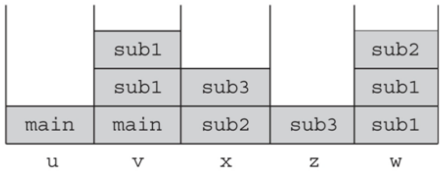
```
void sub3() {
  int x, z;
  x = u + v;
  ...
}
void sub2() {
  int w, x;
  ...
}
void sub1() {
  int v, w;
  ...
}
void main() {
  int v, u;
  ...
}
```

main calls sub1

sub1 calls sub1

sub1 calls sub2

sub2 calls sub3



(The names in the stack cells indicate the program units of the variable declaration.)

```
function joe(int a, int b, int c)
 begin
  a := b + c;
  b := c + 1;
  print a, b, c;
 end
function main
 begin
  int i := 5;
  int j := 10;
  ink k := 15;
  joe(i, j, j + k);
  print i, j, k;
 end
```

1.All parameters are passed by value.

35 26 25

5 10 15 --parameters are independent variables initialized to the values of the argument expressions. Changes to them do not effect the arguments.

2.Pass a and b by reference, and c by value.

35 26 25

35 26 15 --This is very much same,except the changes to a and b are also made to i and j since these parameters are aliases.

3.Pass a and b by value-result, and c by value.

35 26 25

35 26 15 --This has the same effect as pass-by-reference, since the values of a and b are returned to i and j when the function returns.

4.All parameters are passed by name.

35 26 41

35 26 15 --This is again similar to the last two,since changes to a and b also change i and j. The difference is the value of 41 printed for c, since c is an alias for the expression j+k. The assignment b := c + 1 changes b to 26, which changes j, which changes j+k, now 26+15.