Course 6

Problem: Parsing (construct the syntax tree)

if the *source program is sintactically correct*

then construct syntax tree

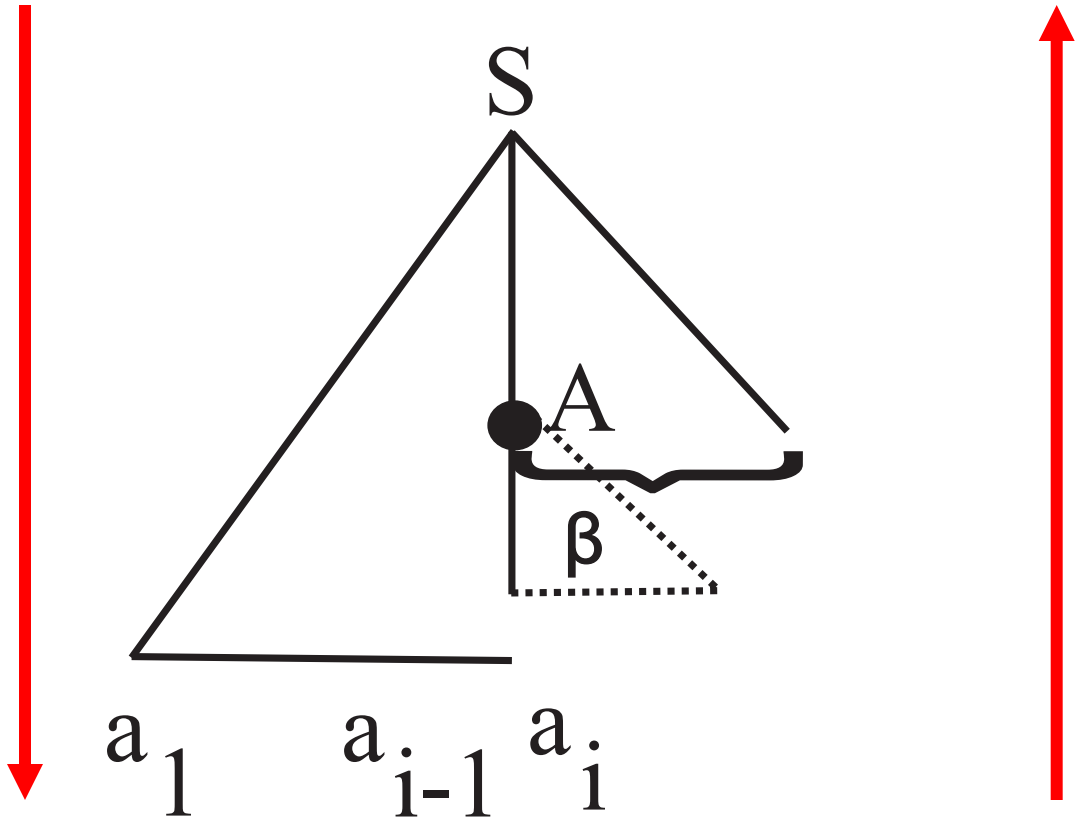
else ”syntax error”

source program is sintactically correct = $w \in L(G) \Leftrightarrow S \overset{*}{\Rightarrow} w$

Parsing

- Cfg G = (N, **Σ**, P,S) check if w ∈ L(G)
- Construct parse/syntax tree

- How:
  1. Top-down vs. Bottom-up
  2. Recursive vs. linear

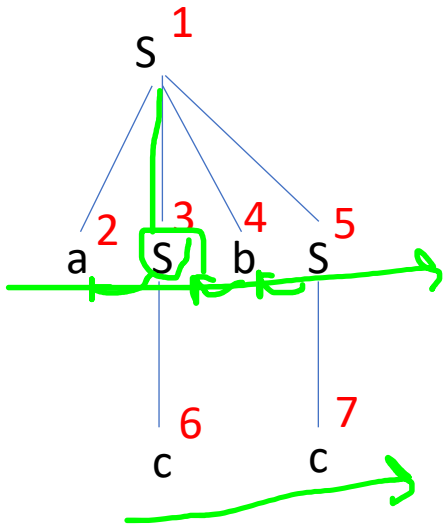


	Descendent	Ascendent
Recursive	Descendent recursive parser	Ascendent recursive parser
Linear	LL(k): LL(1)	LR(k): LR(0), SLR, LR(1), LALR

Result – parse tree -representation

- Arbitrary tree – child sybling representation
- Sequence of derivations S => α_1 => α_2 =>… => α_n = w
- String of production – index associated to prod – which prod is used at each derivation step

index	Info	Parent	Right sibling
1	S	0	0
2	a	1	0
3	S	1	2
4	b	1	3
5	S	1	4
6	c	3	0
7	c	5	0



yacc – Unix tool (Bison – Window version)

- **Yet Another Compiler Compiler**

- LALR
- C code

A yacc grammar file has four main sections

```
%{
C declarations
%}

yacc declarations

%%
Grammar rules
%%

Additional C code
```

contains declarations that define terminal and nonterminal symbols, specify precedence, and so on.

The grammar rules section

- contains one or more yacc grammar rules of the following general form:

```
result: components...   {C statements}

        ;

exp:      exp '+' exp
  ;

result:    rule1-components...
       | rule2-components...
       ...
       ;
result:                  /*empty */
       | rule2-components...
       ;
```

Example: expression interpreter

- input

```
%token DIGIT

%%
line : expr '\n'          { printf("%d\n", $1);}
     ;
expr : expr '+' expr       { $$ = $1 + $3;}
     | expr '*' expr       { $$ = $1 * $3;}
     | '(' expr ')'        { $$ = $2;}
     | DIGIT
     ;
%%
```

- Yacc has a stack of values - referenced ‘$i’ in semantic actions

- Input file (desk0)

```
%%
line : expr '\n'          { printf("%d\n", $1);}
     ;
expr : expr '+' expr      { $$ = $1 + $3;}
     | expr '*' expr      { $$ = $1 * $3;}
     | '(' expr ')'       { $$ = $2;}
     | DIGIT
     ;
```

```
> make desk0
bison -v desk0.y
desk0.y contains 4 shift/reduce conflicts.
gcc -o desk0 desk0.tab.c
>
```

Conflict resolution in yacc

- Conflict **shift-reduce** – prefer **shift**

- Conflict **reduce-reduce** – chose first production

```
%%
line : expr '\n'          { printf("%d\n", $1);}
     ;
expr : expr '+' expr      { $$ = $1 + $3;}
     | expr '*' expr      { $$ = $1 * $3;}
     | '(' expr ')'       { $$ = $2;}
     | DIGIT
     ;
%%
```

- Run yacc
- Run desk0

```
> desk0
2*3+4
14
```

Operator priority in yacc

- From low to great

```
%token DIGIT
%left '+'
%left '*'

%%
line : expr '\n'          { printf("%d\n", $1);}
     ;
expr : expr '+' expr       { $$ = $1 + $3;}
     | expr '*' expr       { $$ = $1 * $3;}
     | '(' expr ')'        { $$ = $2;}
     | DIGIT
     ;
%%
```

%left '-' // 7-4-3 = 0 ✓
%right '-' // 7-4-3 = 6 ✗

- Use

```
>lex spec.lxi
>yacc -d spec.y
>cc lex.yy.c y.tab.c -o rezultat -lfl
>rezultat<fis_intrare
```

- More on

  http://catalog.compilertools.net/lexparse.html

Example

Descendent recursive parser

- Example

Formal model

- Configuration

$$(s, i, \alpha, \beta)$$

where:

- s = state of the parsing, can be:
  - q = normal state
  - b = back state
  - f = final state - corresponding to success: w ∈ L(G)
  - e = error state – corresponding to insuccess: w ∉ L(G)
- i – position of current symbol in input sequence

  $w = a_1 a_2 \ldots a_n$, $i \in \{1,\ldots,n+1\}$
- α = working stack, stores the way the parse is built
- β = input stack, part of the tree to be built

Initial configuration: $(q,1,\varepsilon, S)$

Define moves between configurations

Final configuration: $(f,n+1, \alpha,\varepsilon)$

Expand

WHEN: head of input stack is a nonterminal

$(q,i, \alpha, A\beta) \vdash (q,i, \alpha A_1, \gamma_1\beta)$

where:

$A \rightarrow \gamma_1 \mid \gamma_2 \mid \ldots$ represents the productions corresponding to A

1 = first prod of A

Advance

WHEN: head of input stack is a terminal = current symbol from input

$(q, i, \alpha, a_i\beta) \vdash (q, i+1, \alpha a_i, \beta)$

Momentary insuccess

WHEN: head of input stack is a terminal ≠ current symbol from input

$(q,i,\alpha,a_i\beta) \vdash (b,i,\alpha,\beta)$

Back

WHEN: head of working stack is a terminal

(b,i, αa, β) ⊢ (b,i-1, α, aβ)

Another try

WHEN: head of working stack is a nonterminal

$(b,i,\alpha A_j,\gamma_j\beta) \vdash$ $(q,i,\alpha A_{j+1},\gamma_{j+1}\beta)$, if $\exists\ A \rightarrow \gamma_{j+1}$

$(b,i,\alpha,A\beta)$, otherwise with the exception

(e,i,α,β), if i=1, A =S, **ERROR**

Success

$(q, n+1, \boldsymbol{\alpha}, \varepsilon) \vdash (f, n+1, \boldsymbol{\alpha}, \varepsilon)$

Algorithm

Algorithm Descendent Recursive

INPUT: G, w =$a_1a_2...a_n$
OUTPUT: string of productions and message

```
config = (q,1, ε,S);                                   //initial configuration (s,i,α,β)
while (s ≠ f) and (s ≠ e) do
   if s = q
     then if (i=n+1) and IsEmpty(β)
               then Success(config)
               else
                    if Head(β) = A
                       then Expand(config)
                       else
                          if  Head(β) = a_i
                              then Advance(config)
                              else MomentaryInsuccess(config)
     else
          if s = b
             then
                 if Head(α) = a
                   then Back(config)
                   else AnotherTry(config)
endWhile
if s = e  then message"Error"
          else message "Sequence accepted";
               BuildStringOfProd(α)
```

w ∈ L(G) - HOW

- Process $\boldsymbol{\alpha}$:
  - From left to right (reverse if stored as stack)
  - Skip terminal symbols
  - Nonterminals – index of prod

- Example: $\boldsymbol{\alpha}$ = S_1 a S_2 a S_3 c b S_3 c

When the algorithm will never finish? (loop infinitely)

- A -> Aα |b //left recursive