# Course 6

# Problem: Parsing (construct the parsee tree)

**if** the *source program is sintactically correct*

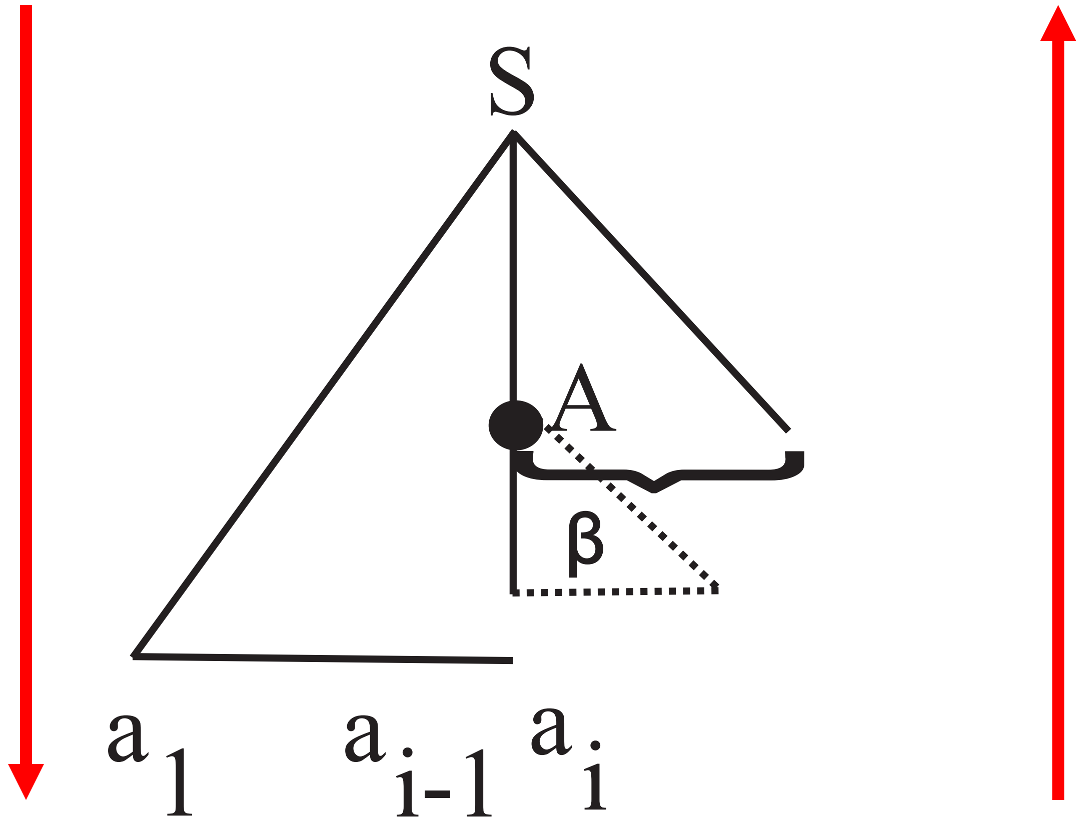
**then** construct syntax tree

**else** ”syntax error”

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

# Parsing

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

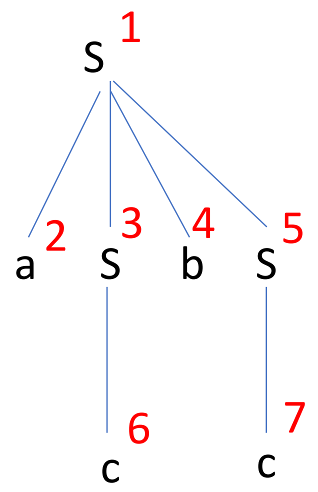


| | Descendent | Ascendent |
|---|---|---|
| Recursive | Descendent recursive parser | Ascendent recursive parser |
| Linear | LL(k): $\boxed{\text{LL(1)}}$ | LR(k): LR(0), SLR, LR(1), $\boxed{\text{LALR}}$ |

# Result – parse tree -representation

- Arbitrary tree – child sybling representation
- Sequence of derivations S => $\alpha_1$ => $\alpha_2$ =>… => $\alpha_n$ = w
- String of production – index associated to prod – which prod is used at each derivation step: 1,4,3,…

| 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 |



# Descendent recursive parser

- Example

S -> aSbS | aS | c

# Formal model

- Configuration

$$(\mathbf{s}, \mathbf{i}, \alpha, \beta)$$

where:

- s = state of the parsing, can be:
  - q = normal state
  - b = back state
  - f = final state - corresponding to success: $w \in L(G)$
  - e = error state – corresponding to insuccess: $w \notin L(G)$
- i – position of current symbol in input sequence
  $w = a_1a_2\ldots a_n$, $i \in \{1,\ldots,n+1\}$
- $\alpha$ = working stack, stores the way the parse is built
- $\beta$ = 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

$(q, i, \boldsymbol{\alpha}, A\boldsymbol{\beta}) \vdash (q, i, \boldsymbol{\alpha}A_1, \boldsymbol{\gamma}_1\boldsymbol{\beta})$

where:

$A \rightarrow \boldsymbol{\gamma}_1 \mid \boldsymbol{\gamma}_2 \mid \ldots$ represents the productions corresponding to A

1 = first prod of A

# Advance

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

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

# Momentary insuccess

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

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

# Back

WHEN: head of working stack is a terminal

$(b,i,\boldsymbol{\alpha}a,\boldsymbol{\beta}) \vdash (b,i-1,\boldsymbol{\alpha},a\boldsymbol{\beta})$

# Another try

WHEN: head of working stack is a nonterminal

$(b,i, \boldsymbol{\alpha}\, A_j, \boldsymbol{\gamma}_j \boldsymbol{\beta}) \vdash$ $(q,i, \boldsymbol{\alpha} A_{j+1}, \boldsymbol{\gamma}_{j+1}\boldsymbol{\beta})$ , if $\exists\, A \rightarrow \boldsymbol{\gamma}_{j+1}$

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

$(e,i, \boldsymbol{\alpha}, \boldsymbol{\beta})$, 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

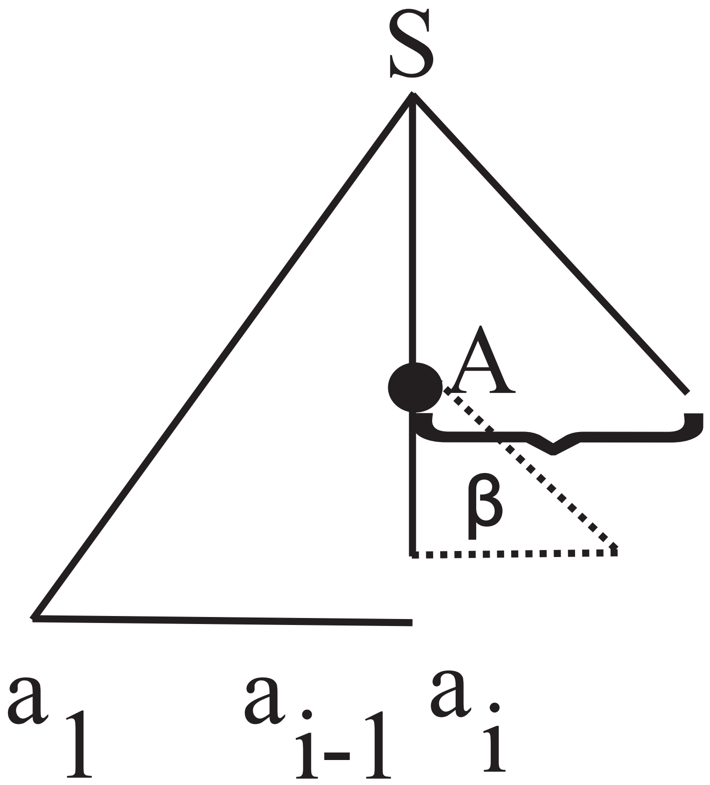
- Process $\boldsymbol{\alpha}$:
  - From left to right (reverse if stored as stack)
  - Skip terminal symbols
  - Nonterminals – index of prod

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

# When the algorithm never stops?

- S->S**$\alpha$** – expand infinitely (left recursive)

# LL(1) Parser




Linear algorithm

# $\text{FIRST}_k$

- ≈ first k terminal symbols that can be generated from $\alpha$
- **Definition**:

$$FIRST_k : (N \cup \Sigma)^* \rightarrow \mathcal{P}(\Sigma^k)$$
$$FIRST_k(\alpha) = \{u|u \in \Sigma^k, \alpha \overset{*}{\Rightarrow} ux, |u| = k \text{ sau } \alpha \overset{*}{\Rightarrow} u, |u| \leq k\}$$