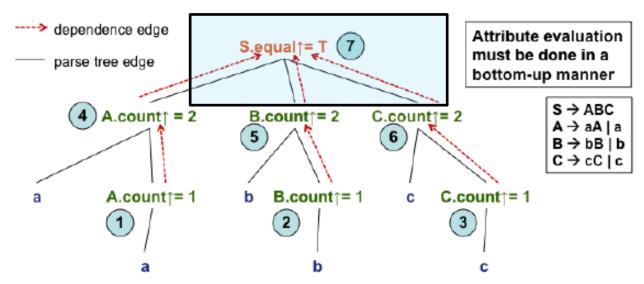
CC Lecture 20 & 21

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Attribute Grammar - Example 1



- $S \rightarrow ABC$ { $S.equal \uparrow := if A.count \uparrow = B.count \uparrow & B.count \uparrow = C.count \uparrow then T else F}$
- $A_1 \rightarrow aA_2 \{A_1.count \uparrow := A_2.count \uparrow +1\}$

- B → b {B.count ↑:= 1}
- $O \subset C \rightarrow c \{C.count \uparrow := 1\}$

Attribute Dependence Graph

- Let T be a parse tree generated by the CFG of an AG, G.
- The attribute dependence graph (dependence graph for short) for T is the directed graph, DG(T) = (V, E), where

V = {b|b is an attribute instance of some tree node}

 $E = \{(b, c) | b, c \in V, b \text{ and } c \text{ are attributes of grammar symbols}$ in the same production p of B, and the value of b is used for computing the value of c in an attribute computation rule associated with production p}

Attribute Dependence Graph

- An AG(attribute grammar) G is **non-circular**, if and only if for all trees T derived from G, DG(T) is acyclic
 - Non-circularity is very expensive to determine (exponential in the size of the grammar)
 - Therefore, our interest will be in subclasses of AGs whose non-circularity can be determined efficiently
- Assigning consistent values to the attribute instances in DG(T) is attribute evaluation.

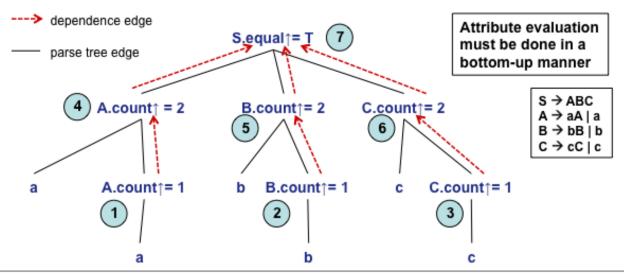
Attribute Evaluation Strategy

- Construct the parse tree
- Construct the dependence graph
- Perform topological sort on the dependence graph and obtain an evaluation order
- Evaluate attributes according to this order using the corresponding attribute evaluation rules attached to the respective productions
- Multiple attributes at a node in the parse tree may result in that node to be visited multiple number of times
 - Each visit resulting in the evaluation of at least one attribute

Attribute Evaluation Algorithm

```
Input: A parse tree T with unevaluated attribute instances
       Output: T with consistent attribute values
       { Let (V, E) = DG(T);
(W is a queue) Let W = \{b \mid b \in V \& indegree(b) = 0\};
         while W \neq \phi do
           { remove some b from W;
              value(b) := value defined by appropriate attribute
                          computation rule;
              for all (b, c) \in E do
               { indegree(c) := indegree(c) - 1;
                 if indegree(c) = 0 then W := W \cup \{c\};
```

Dependence Graph for Example 1



1,2,3,4,5,6,7 and 2,3,6,5,1,4,7 are two possible evaluation orders. 1,4,2,5,3,6,7 can be used with LR-parsing. The right-most derivation is below (its reverse is LR-parsing order)

S => ABC => ABcC => ABcc => AbBcc => Abbcc => aAbbcc => aabbcc

- 1. A.count = 1 $\{A \rightarrow a, \{A.count := 1\}\}$
- 4. A.count = $2\{A_1 \rightarrow aA_2, \{A_1.count := A_2.count + 1\}\}$
- 2. B.count = 1 {B → b, {B.count :=1}}
- 5. B.count = $2\{B_1 \rightarrow bB_2, \{B_1.count := B_2.count + 1\}\}$
- 3. C.count = 1 {C \rightarrow c, {C.count :=1}}
- 6. C.count = $2\{C_1 \rightarrow cC_2, \{C_1.count := C_2.count + 1\}\}$
- S.equal = 1 {S → ABC, {S.equal := if A.count = B.count & B.count = C.count then T else F}}

Syntax Directed Translation

=

Grammar + Semantic Rules

```
S → ABC 

B.count ↑= B.count ↑ & B.count ↑ & B.count ↑ = B.count ↑ & B.count ↑= C.count ↑ then T else F}

A → aA | a
B → bB | b
C → cC | c

S → ABC {S.equal ↑:= if A.count ↑ = B.count ↑ & B.count ↑ = C.count ↑ then T else F}

A<sub>1</sub> → aA<sub>2</sub> {A<sub>1</sub>.count ↑:= A<sub>2</sub>.count ↑ +1}

A → a {A.count ↑:= 1}
B → b {B.count ↑:= 1}
C → cC<sub>2</sub> {C<sub>1</sub>.count ↑:= C<sub>2</sub>.count ↑ +1}

C → c {C.count ↑:= 1}
```

Example 2

 Write an attribute grammar for the evaluation of a real number from its bit-string representation.

• Example: $(110.101)_2 = (6.625)_{10}$

110	•	101
110 → 6		101 → 5
		(decimal value)/(2^ no. of bits) = 5 / 2^3 = 5 / 8 = 0.625

Example 2

 Write an attribute grammar for the evaluation of a real number from its bit-string representation.

$$N \rightarrow L.L$$

$$L \rightarrow BL \mid B$$

$$B \rightarrow 0 \mid 1$$

Example 2

```
N \rightarrow L.L
    L \rightarrow BL \mid B
    B \rightarrow 0|1

    AS(N)= AS(B) ={val个:real}

    AS(L) ={cnt个:integer, val个:real}

1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
2. L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3. L \rightarrow B {L.cnt = 1; L.val = B.val}
4. B \rightarrow 0 {B.val = 0}
```

5. $B \rightarrow 1$ {B.val = 1}

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                    \{B.val = 0\}
5.
     B \rightarrow 1
                      \{B.val = 1\}
                                                    Ν
                   В
```

В

Example: $(110.101)_2 = (6.625)_{10}$

В

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                    \{B.val = 0\}
5.
     B \rightarrow 1
                      \{B.val = 1\}
                                                    Ν
                   В
```

Example: $(110.101)_2 = (6.625)_{10}$ B

0

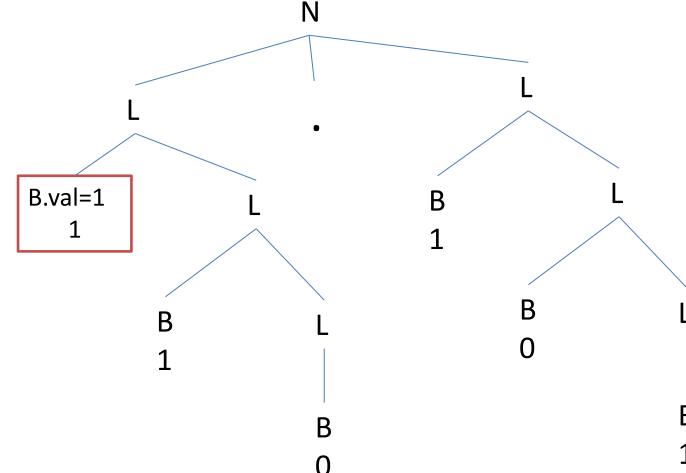
```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}

2. L \rightarrow BL_1 {L.cnt=L_1.cnt+1; L.val=L_1.val+(B.val* 2^L_1.cnt)}

3. L \rightarrow B {L.cnt = 1 ; L.val = B.val}

4. B \rightarrow 0 {B.val = 0}

5. B \rightarrow 1 {B.val = 1}
```



```
N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
2.
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
4.
     B \rightarrow 0
                     \{B.val = 0\}
     B \rightarrow 1
                      {B.val = 1}
                                                    N
                   B.val=1
```

B.val=1

1

```
N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
2.
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0 {B.val = 0}
5.
     B \rightarrow 1
                     \{B.val = 1\}
                                                   N
                  B.val=1
                                 B.val=1
```

B.val=0

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
2.
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
4.
     B \rightarrow 0
                   \{B.val = 0\}
5.
     B \rightarrow 1
                      \{B.val = 1\}
                                                  N
                  B.val=1
                                 B.val=1
                                                    L.cnt=1
                                                    L.val=0
                                                    B.val=0
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
4.
                   \{B.val = 0\}
5.
     B \rightarrow 1
                     \{B.val = 1\}
                                                 N
                 B.val=1
                                   L.cnt=2
                                                                В
                                   L.val=0+(1*2^1)=2
                                B.val=1
                                                   L.cnt=1
                                     1
                                                   L.val=0
                                                                                            В
                                                   B.val=0
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
4.
                  \{B.val = 0\}
5.
     B \rightarrow 1
                     {B.val = 1}
                                                N
                      L.cnt=3
                      L.val=2+(1*2^2)=6
                 B.val=1
                                          L.cnt=2
                                           L.val=2
                                B.val=1
                                                  L.cnt=1
                                     1
                                                  L.val=0
                                                                                            В
                                                  B.val=0
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
2.
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
4.
                  \{B.val = 0\}
     B \rightarrow 1
                    \{B.val = 1\}
                                                N
                              L.cnt=3
                              L.val=6
                 B.val=1
                                                               B.val=1
                                          L.cnt=2
                                           L.val=2
                                B.val=1
                                                  L.cnt=1
                                     1
                                                  L.val=0
                                                                                            В
                                                  B.val=0
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0 {B.val = 0}
5.
     B \rightarrow 1
                    \{B.val = 1\}
                                                N
                              L.cnt=3
                              L.val=6
                 B.val=1
                                                              B.val=1
                                          L.cnt=2
                                          L.val=2
                                                                         B.val=0
                                B.val=1
                                                  L.cnt=1
                                     1
                                                  L.val=0
                                                                                           В
                                                  B.val=0
```

```
N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
2.
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                  \{B.val = 0\}
     B \rightarrow 1
                    \{B.val = 1\}
                                                 N
                              L.cnt=3
                              L.val=6
                 B.val=1
                                                               B.val=1
                                           L.cnt=2
                                           L.val=2
                                                                          B.val=0
                                B.val=1
                                                  L.cnt=1
                                                                              0
                                     1
                                                  L.val=0
                                                                                        B.val=1
                                                  B.val=0
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
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     B \rightarrow 0 {B.val = 0}
5.
     B \rightarrow 1
                     {B.val = 1}
                                                N
                              L.cnt=3
                              L.val=6
                                                              B.val=1
                 B.val=1
                                          L.cnt=2
                                          L.val=2
                                                                         B.val=0
                                                                                           L.cnt=1
                                B.val=1
                                                  L.cnt=1
                                                                             0
                                                                                           L.val=1
                                    1
                                                  L.val=0
                                                                                           B.val=1
                                                  B.val=0
                                                                                               1
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                    \{B.val = 0\}
5.
     B \rightarrow 1
                     \{B.val = 1\}
                                                N
                              L.cnt=3
                              L.val=6
                                                                               L.cnt=2
                                                              B.val=1
                 B.val=1
                                          L.cnt=2
                                                                               L.val=1+(0*2^1)=1
                                          L.val=2
                                                                         B.val=0
                                                                                           L.cnt=1
                                B.val=1
                                                  L.cnt=1
                                                                             0
                                                                                           L.val=1
                                    1
                                                  L.val=0
                                                                                           B.val=1
                                                  B.val=0
                                                                                               1
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                   \{B.val = 0\}
5.
     B \rightarrow 1
                     \{B.val = 1\}
                                                N
                                                                        L.cnt=3
                              L.cnt=3
                                                                        L.val=1+(1*2^2)=5
                              L.val=6
                                                                               L.cnt=2
                                                              B.val=1
                 B.val=1
                                          L.cnt=2
                                                                               L.val=1
                                          L.val=2
                                                                        B.val=0
                                                                                          L.cnt=1
                               B.val=1
                                                 L.cnt=1
                                                                             0
                                                                                          L.val=1
                                    1
                                                 L.val=0
                                                                                          B.val=1
                                                 B.val=0
                                                                                               1
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                  \{B.val = 0\}
     B \rightarrow 1
                     \{B.val = 1\}
5.
                                      N.val=6+(5/2^3)=6.625
                                                                        L.cnt=3
                              L.cnt=3
                                                                        L.val=5
                              L.val=6
                                                                              L.cnt=2
                                                             B.val=1
                 B.val=1
                                         L.cnt=2
                                                                               L.val=1
                                          L.val=2
                                                                        B.val=0
                                                                                         L.cnt=1
                               B.val=1
                                                 L.cnt=1
                                                                            0
                                                                                          L.val=1
                                    1
                                                 L.val=0
                                                                                          B.val=1
                                                 B.val=0
                                                                                              1
```

```
N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow BL_1 {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val+(B.val* 2^L<sub>1</sub>.cnt)}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                     \{B.val = 0\}
     B \rightarrow 1
5.
                     \{B.val = 1\}
                                           N.val=6.625
                                                                         L.cnt=3
                              L.cnt=3
                                                                         L.val=5
                              L.val=6
                                                                                L.cnt=2
                 B.val=1
                                                              B.val=1
                                          L.cnt=2
                                                                                L.val=1
                                          L.val=2
                                                                         B.val=0
                                                                                           L.cnt=1
                                B.val=1
                                                  L.cnt=1
                                                                             0
                                                                                           L.val=1
                                    1
                                                  L.val=0
                                                                                           B.val=1
                                                  B.val=0
                                                                                               1
```

Example 2 (second method)

 Write an attribute grammar for the evaluation of a real number from its bit-string representation.

• Example: $(110.101)_2 = (6.625)_{10}$

110	•	101
110 → 6		(decimal value)/(2^ no. of bits) = 5 / 2^3 = 5 / 8 = 0.625

Example 2 (second method)

 Write an attribute grammar for the evaluation of a real number from its bit-string representation.

$$N \rightarrow L.L$$

$$L \rightarrow LB \mid B$$

$$B \rightarrow 0 \mid 1$$

Example 2 (second method)

```
N \rightarrow L.L
L \rightarrow LB \mid B
B \rightarrow 0 \mid 1
```

- AS(N)=AS(B)={val个:real}
- AS(L) ={cnt个:integer, val个:real}
- 1. $N \rightarrow L_1.L_2 \{N.val = L_1.val + (L_2.val / 2^L_2.cnt)\}$
- 2. $L \rightarrow L_1B$ {L.cnt= L_1 .cnt+1; L.val= L_1 .val*2 + B.val}
- 3. $L \rightarrow B$ {L.cnt = 1; L.val = B.val}
- 4. $B \rightarrow 0$ {B.val = 0}
- 5. $B \rightarrow 1$ {B.val = 1}

```
N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
2.
     L \rightarrow L_1B
                    \{L.cnt=L_1.cnt+1; L.val=L_1.val*2 + B.val\}
3.
     L \rightarrow B
                      {L.cnt = 1 ; L.val = B.val}
4.
     B \rightarrow 0
                      \{B.val = 0\}
5.
     B \rightarrow 1
                      {B.val = 1}
                                                                                        В
                                            В
```

В

В

В

В

```
N \rightarrow L_1.L_2 \quad \{N.val = L_1.val + (L_2.val / 2^L_2.cnt)\}
2.
     L \rightarrow L_1B
                     \{L.cnt=L_1.cnt+1; L.val=L_1.val*2 + B.val\}
3.
     L \rightarrow B
                       {L.cnt = 1 ; L.val = B.val}
     B \rightarrow 0
4.
                       \{B.val = 0\}
                       \{B.val = 1\}
5.
     B \rightarrow 1
                                                                                           В
                                             В
                            В
                                                        В
        В
```

```
N \rightarrow L_1.L_2 \quad \{N.val = L_1.val + (L_2.val / 2^L_2.cnt)\}
2.
     L \rightarrow L_1B
                     \{L.cnt=L_1.cnt+1; L.val=L_1.val*2 + B.val\}
3.
     L \rightarrow B
                      {L.cnt = 1 ; L.val = B.val}
     B \rightarrow 0
4.
                      \{B.val = 0\}
     B \rightarrow 1
                      {B.val = 1}
                                                                                          В
                                             В
                           В
```

B.val=1 1

1

```
N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
2.
     L \rightarrow L_1B
                    \{L.cnt=L_1.cnt+1; L.val=L_1.val*2 + B.val\}
3.
     L \rightarrow B
                    {L.cnt = 1 ; L.val = B.val}
     B \rightarrow 0
                     \{B.val = 0\}
5.
     B \rightarrow 1
                     {B.val = 1}
                                                                                      В
                                          В
                          В
   L.cnt=1
   L.val=1
   B.val=1
```

```
N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
2.
     L \rightarrow L_1B
                   \{L.cnt=L_1.cnt+1; L.val=L_1.val*2 + B.val\}
3.
     L \rightarrow B
                     {L.cnt = 1 ; L.val = B.val}
     B \rightarrow 0
                     \{B.val = 0\}
     B \rightarrow 1
                     {B.val = 1}
                                                                                     В
                                          В
                          B.val=1
   L.cnt=1
   L.val=1
   B.val=1
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
3.
                   \{L.cnt = 1 ; L.val = B.val\}
     L \rightarrow B
     B \rightarrow 0
4.
                      \{B.val = 0\}
5.
     B \rightarrow 1
                      {B.val = 1}
                                                                                       В
          L.cnt=1+1=2
                                           В
          L.val=1*2 + 1=3
                          B.val=1
   L.cnt=1
   L.val=1
   B.val=1
```

```
N \rightarrow L_1.L_2 \{N.val = L_1.val + (L_2.val / 2^L_2.cnt)\}
     L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
3.
     L \rightarrow B
                   \{L.cnt = 1 ; L.val = B.val\}
     B \rightarrow 0
                     \{B.val = 0\}
5.
     B \rightarrow 1
                      \{B.val = 1\}
                                                                                         В
              L.cnt=2
                                            B.val=0
              L.val=3
                           B.val=1
   L.cnt=1
   L.val=1
   B.val=1
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                    \{B.val = 0\}
5.
     B \rightarrow 1
                     \{B.val = 1\}
                                                N
                      L.cnt=2+1=3
                      L.val=3*2+0=6
                                                                                     В
             L.cnt=2
                                          B.val=0
             L.val=3
                                              0
                          B.val=1
   L.cnt=1
   L.val=1
   B.val=1
```

```
N \rightarrow L_1.L_2 \{N.val = L_1.val + (L_2.val / 2^L_2.cnt)\}
     L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                    \{B.val = 0\}
     B \rightarrow 1
                     {B.val = 1}
                                                 N
                           L.cnt=3
                           L.val=6
                                                                                      В
             L.cnt=2
                                           B.val=0
             L.val=3
                          B.val=1
   L.cnt=1
   L.val=1
                                                 B.val=1
   B.val=1
                                                      1
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                    \{B.val = 0\}
5.
     B \rightarrow 1
                     {B.val = 1}
                                                N
                           L.cnt=3
                           L.val=6
                                                                                     В
             L.cnt=2
                                          B.val=0
             L.val=3
                                                                       В
                                                    L.cnt=1
                          B.val=1
   L.cnt=1
                                                    L.val=1
   L.val=1
                                                    B.val=1
   B.val=1
                                                         1
```

```
N \rightarrow L_1.L_2 \{N.val = L_1.val + (L_2.val / 2^L_2.cnt)\}
     L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                   \{B.val = 0\}
5.
     B \rightarrow 1
                     {B.val = 1}
                                                N
                           L.cnt=3
                           L.val=6
                                                                                     В
             L.cnt=2
                                          B.val=0
             L.val=3
                                                                       B.val=0
                                                    L.cnt=1
                          B.val=1
   L.cnt=1
                                                                            0
                                                    L.val=1
   L.val=1
                                                    B.val=1
   B.val=1
                                                         1
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
    L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                    \{B.val = 0\}
5.
     B \rightarrow 1
                     {B.val = 1}
                                               N
                          L.cnt=3
                          L.val=6
                                                                                   В
                                                         L.cnt=1+1=2
             L.cnt=2
                                         B.val=0
                                                                                   1
                                                         L.val=1*2+0=2
             L.val=3
                                                                     B.val=0
                                                   L.cnt=1
                         B.val=1
  L.cnt=1
                                                                          0
                                                   L.val=1
   L.val=1
                                                   B.val=1
  B.val=1
                                                        1
```

```
N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                     \{B.val = 0\}
     B \rightarrow 1
                     {B.val = 1}
                                                N
                          L.cnt=3
                           L.val=6
                                                             L.cnt=2
                                                                                    B.val=1
             L.cnt=2
                                          B.val=0
                                                             L.val=2
             L.val=3
                                                                       B.val=0
                                                    L.cnt=1
                          B.val=1
  L.cnt=1
                                                                           0
                                                    L.val=1
                              1
   L.val=1
                                                    B.val=1
   B.val=1
                                                         1
```

```
1. N \rightarrow L_1.L_2
                   {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
     L \rightarrow B {L.cnt = 1; L.val = B.val}
3.
     B \rightarrow 0
                     \{B.val = 0\}
     B \rightarrow 1
5.
                     {B.val = 1}
                                               N
                                                                       L.cnt=2+1=3
                          L.cnt=3
                                                                       L.val=2*2+1=5
                          L.val=6
                                                             L.cnt=2
                                                                                   B.val=1
             L.cnt=2
                                         B.val=0
                                                             L.val=2
             L.val=3
                                                                      B.val=0
                                                   L.cnt=1
                         B.val=1
   L.cnt=1
                                                                          0
                                                   L.val=1
   L.val=1
                                                   B.val=1
   B.val=1
                                                        1
```

```
1. N \rightarrow L_1.L_2 {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
    L \rightarrow L_1B {L.cnt=L_1.cnt+1; L.val=L_1.val*2 + B.val}
3.
    L \rightarrow B {L.cnt = 1; L.val = B.val}
    B \rightarrow 0
                    \{B.val = 0\}
    B \rightarrow 1
5.
                    \{B.val = 1\}
                                       N.val=6+(5/2^3)=6.625
                                                                    L.cnt=3
                         L.cnt=3
                                                                    L.val=5
                         L.val=6
                                                          L.cnt=2
                                                                                B.val=1
            L.cnt=2
                                       B.val=0
                                                          L.val=2
            L.val=3
                                            0
                                                                   B.val=0
                                                 L.cnt=1
                        B.val=1
  L.cnt=1
                                                                       0
                                                 L.val=1
                            1
  L.val=1
                                                 B.val=1
  B.val=1
                                                     1
```

```
N \rightarrow L_1.L_2
                   {N.val = L_1.val + (L_2.val / 2^L_2.cnt)}
     L \rightarrow L_1B {L.cnt=L<sub>1</sub>.cnt+1; L.val=L<sub>1</sub>.val*2 + B.val}
3.
     L \rightarrow B {L.cnt = 1; L.val = B.val}
     B \rightarrow 0
                     \{B.val = 0\}
     B \rightarrow 1
5.
                     {B.val = 1}
                                         N.val=6.625
                                                                        L.cnt=3
                          L.cnt=3
                                                                        L.val=5
                          L.val=6
                                                             L.cnt=2
                                                                                    B.val=1
             L.cnt=2
                                          B.val=0
                                                             L.val=2
             L.val=3
                                              0
                                                                      B.val=0
                                                    L.cnt=1
                         B.val=1
   L.cnt=1
                                                                           0
                                                    L.val=1
                              1
   L.val=1
                                                    B.val=1
   B.val=1
                                                        1
```

Given a grammar:

```
E \rightarrow E + T | T
T \rightarrow T * F | F
F \rightarrow num
```

- What are the semantic rules(informal notations) for this grammar?
 - There can be a 'value' attribute for E, T and F. (non-terminals)
 - There can be a 'lexvalue' attribute for num (terminal)

Given a grammar:

$$E \rightarrow E + T | T$$

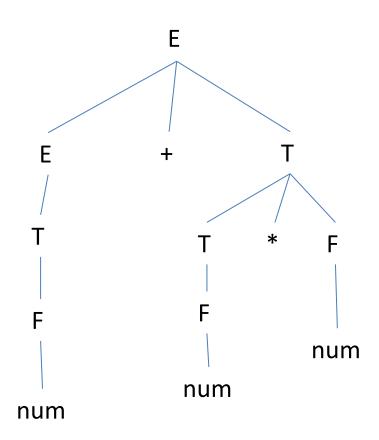
$$T \rightarrow T * F | F$$

$$F \rightarrow num$$

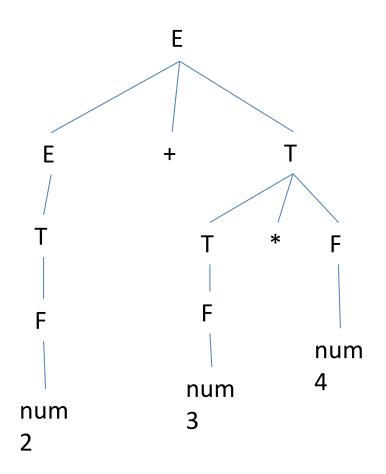
- 1. $E \rightarrow E + T \{ E.value = E.value + T.value \}$
- 2. $E \rightarrow T$ {E.value = T.value}
- 3. $T \rightarrow T * F \{T.value = T.value * F.value\}$
- 4. $T \rightarrow F$ {T.value = F.value}
- 5. $F \rightarrow \text{num } \{F.\text{value} = \text{num.lexvalue}\}$

```
    E → E + T { E.value = E.value + T.value} • Parse Tree??
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```

```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```



```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```

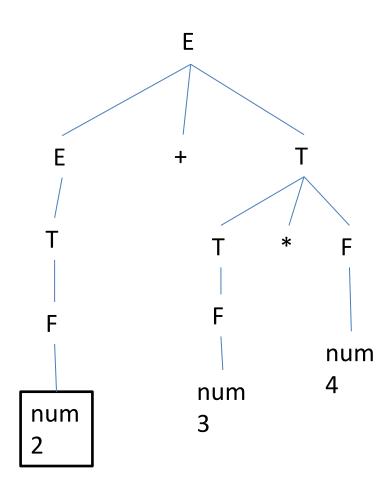


```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
```

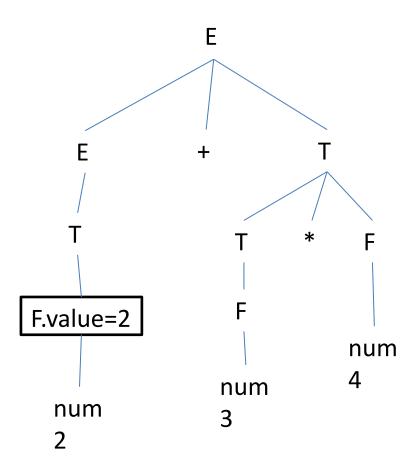
{F.value = num.lexvalue}

For input, 2 + 3 * 4

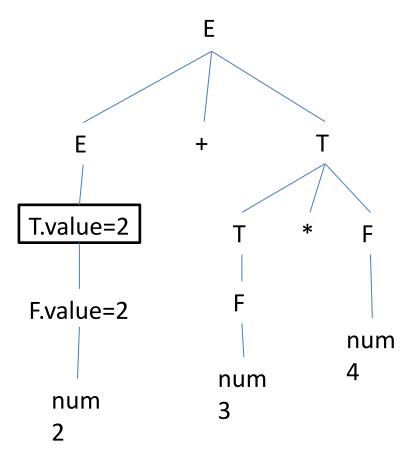
5. $F \rightarrow num$



```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```

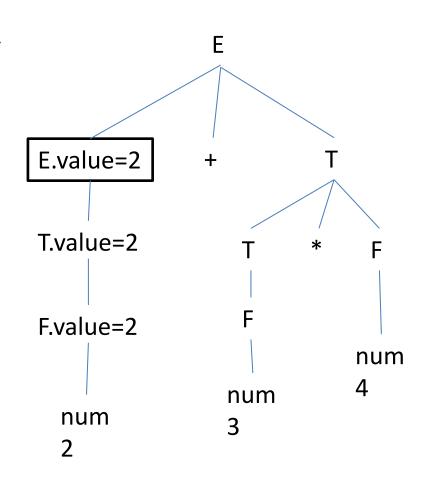


```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```



```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
```

5. $F \rightarrow \text{num}$ {F.value = num.lexvalue}

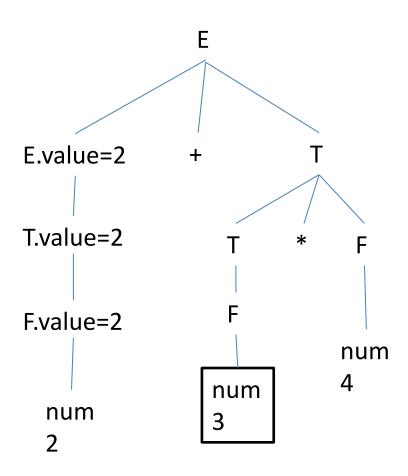


```
1. E \rightarrow E + T { E.value = E.value + T.value}
2. E \rightarrow T {E.value = T.value}
```

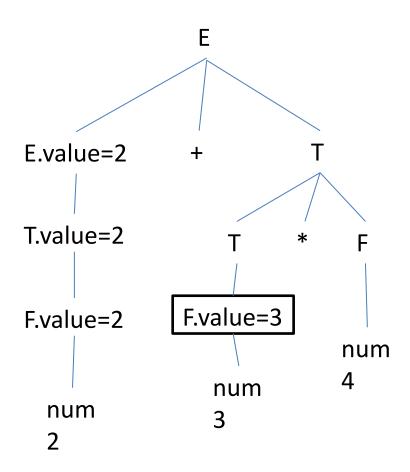
3.
$$T \rightarrow T * F$$
 {T.value = T.value * F.value}

4.
$$T \rightarrow F$$
 {T.value = F.value}

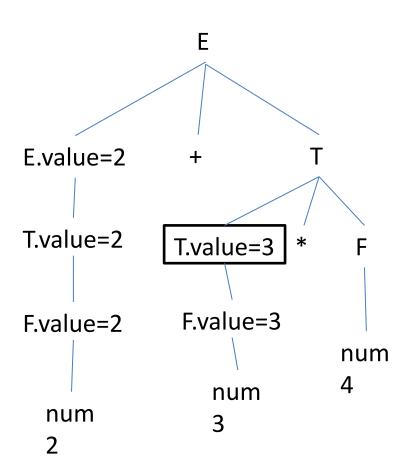
5.
$$F \rightarrow \text{num}$$
 {F.value = num.lexvalue}



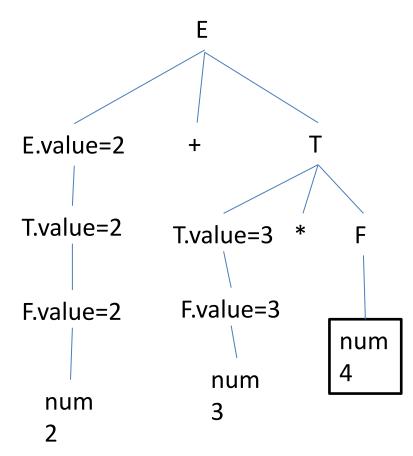
```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```



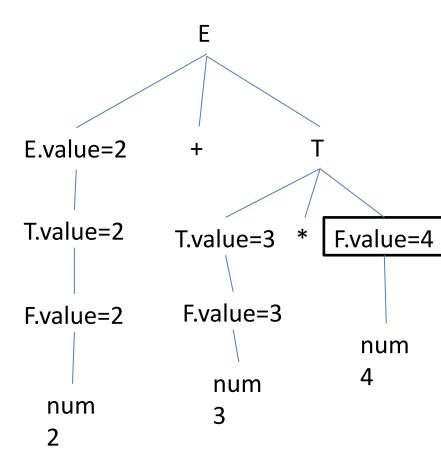
```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```



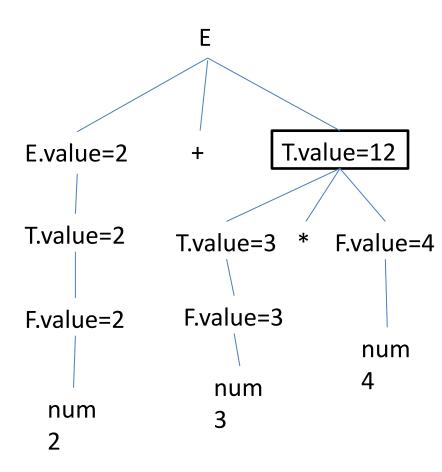
```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```



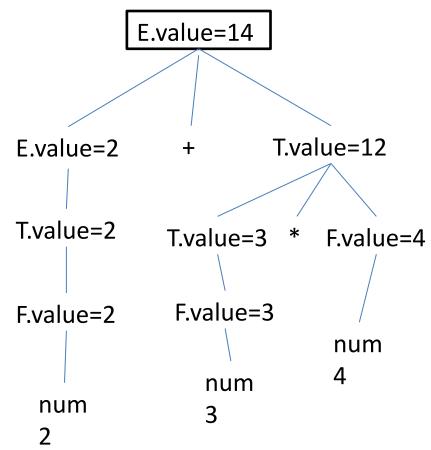
```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```



```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```



```
    E → E + T { E.value = E.value + T.value}
    E → T { E.value = T.value}
    T → T * F { T.value = T.value * F.value}
    T → F { T.value = F.value}
    F → num { F.value = num.lexvalue}
```



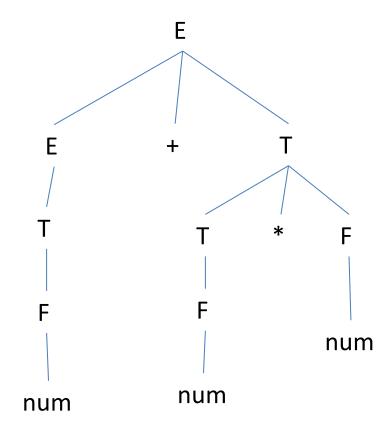
Write SDT to convert infix to postfix

For input, 2 + 3 * 4

Output: 2 3 4 * +

• SDT to convert infix to postfix

$$E \rightarrow E + T$$
 {printf("+");}
 $E \rightarrow T$ {}
 $T \rightarrow T * F$ {printf("*");}
 $T \rightarrow F$ {}
 $F \rightarrow \text{num}$ {printf(num.lval);}



• SDT to convert infix to postfix

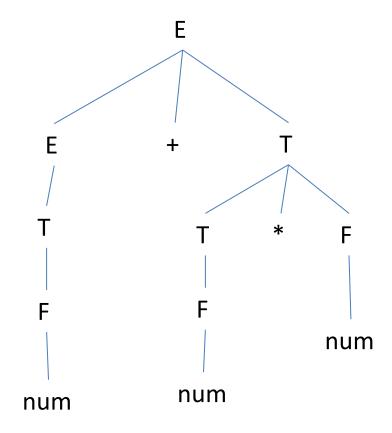
$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

$$E \rightarrow T \qquad \{\} \qquad 2$$

$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\}$$



• SDT to convert infix to postfix

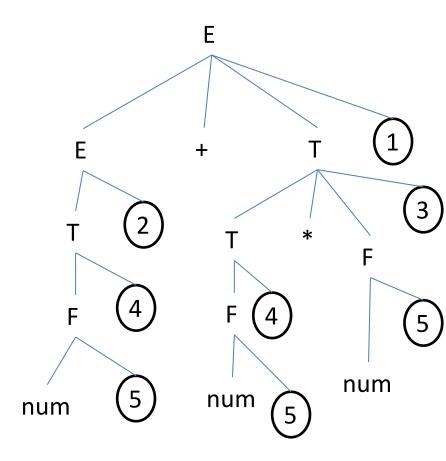
$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

$$E \rightarrow T \qquad \{\} \qquad 2$$

$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\} \qquad (5)$$



• SDT to convert infix to postfix

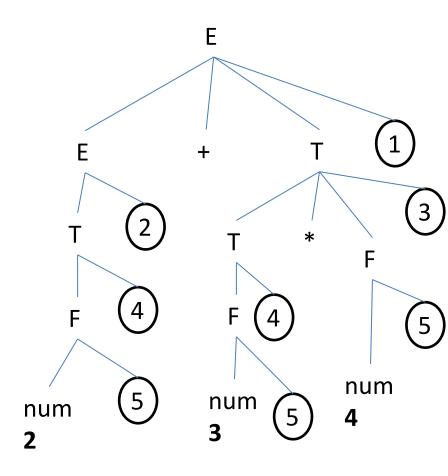
$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

$$E \rightarrow T \qquad \{\} \qquad 2$$

$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\} \qquad (5)$$



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

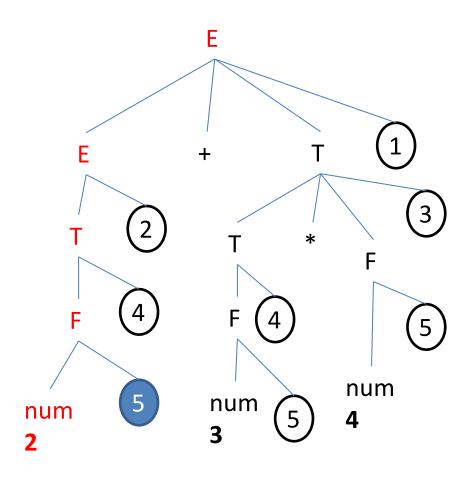
$$E \rightarrow T \qquad \{\} \qquad 2$$

$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\}$$

For input, 2 + 3 * 4



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

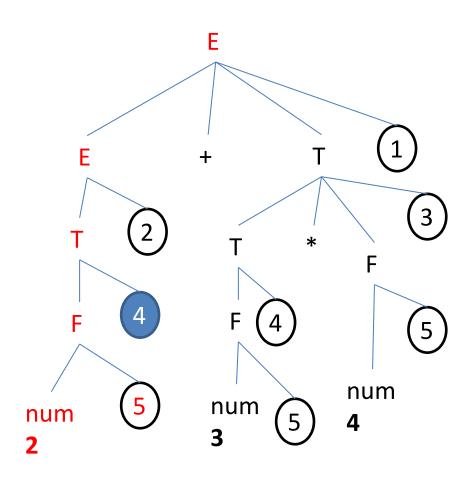
$$E \rightarrow T \qquad \{\} \qquad 2$$

$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\} \qquad (5)$$

For input, 2 + 3 * 4



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

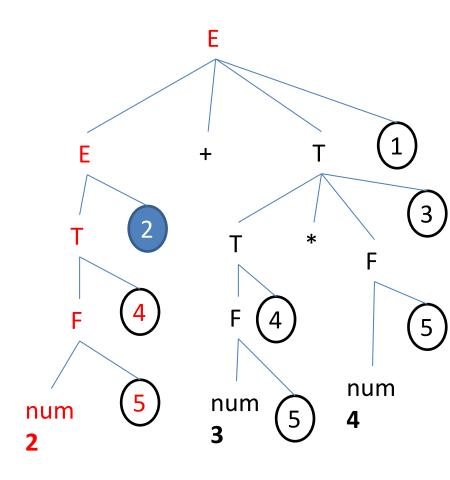
$$E \rightarrow T \qquad \{\} \qquad 2$$

$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\} \qquad (5)$$

For input, 2 + 3 * 4



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

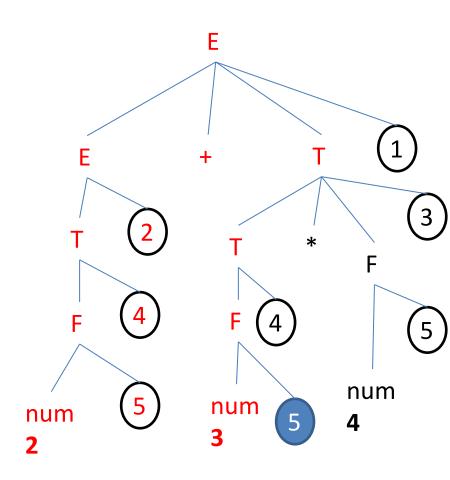
$$E \rightarrow T \qquad \{\} \qquad 2$$

$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\}$$

For input, 2 + 3 * 4



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

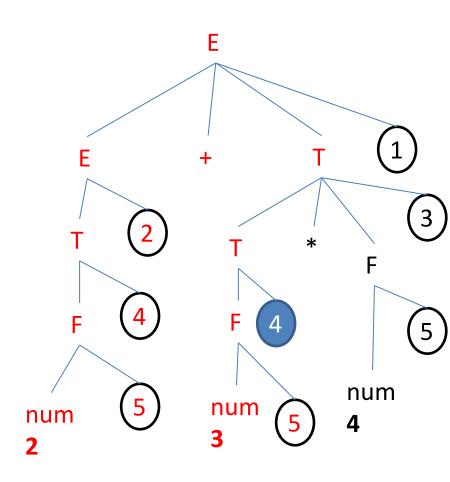
$$E \rightarrow T \qquad \{\} \qquad 2$$

$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\} \qquad (5)$$

For input, 2 + 3 * 4



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

$$E \rightarrow T \qquad \{\} \qquad 2$$

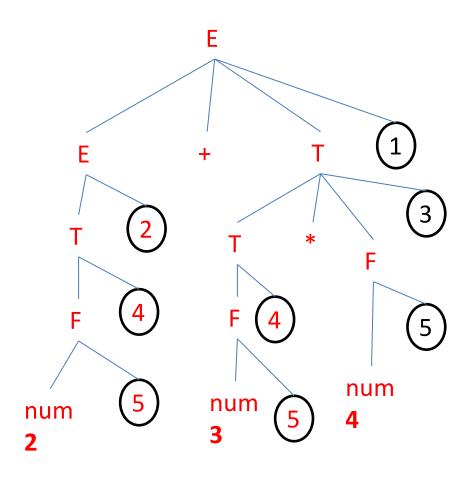
$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\} \qquad (5)$$

For input, 2 + 3 * 4

Output: 23



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

$$E \rightarrow T \qquad \{\} \qquad 2$$

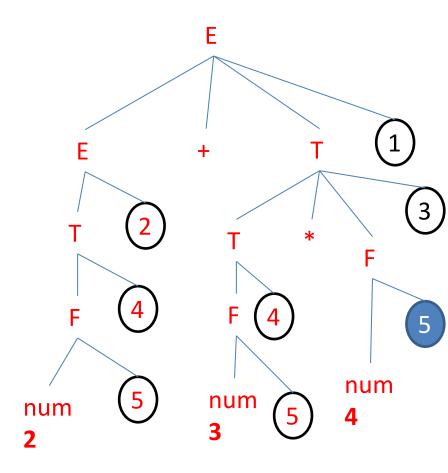
$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\}$$

For input, 2 + 3 * 4

Output: 234



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

$$E \rightarrow T \qquad \{\} \qquad 2$$

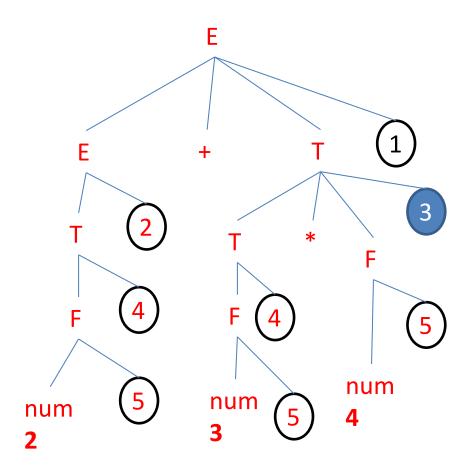
$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\} \qquad (5)$$

For input, 2 + 3 * 4

Output: 234*



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

$$E \rightarrow T \qquad \{\} \qquad 2$$

$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

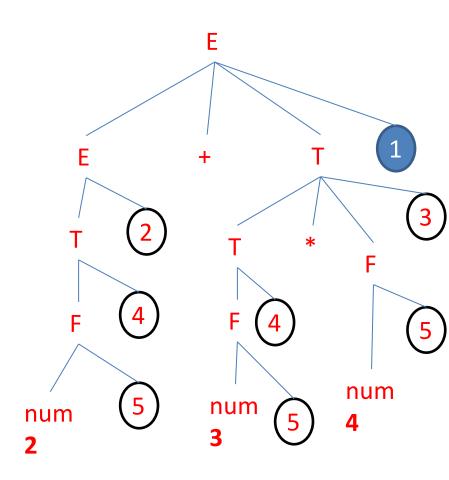
$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\}$$

$$5$$

For input, 2 + 3 * 4

Output: 234*+



• SDT to convert infix to postfix

$$E \rightarrow E + T \qquad \{printf("+");\} \qquad 1$$

$$E \rightarrow T \qquad \{\} \qquad 2$$

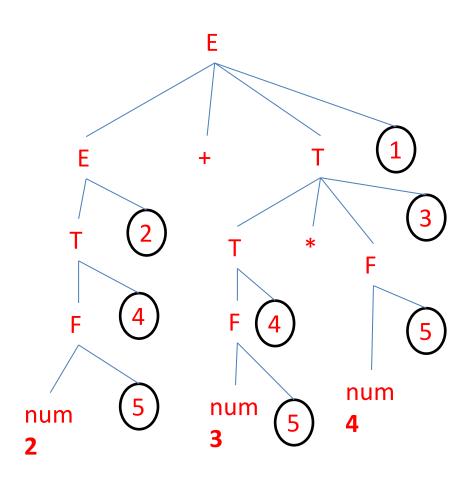
$$T \rightarrow T * F \qquad \{printf("*");\} \qquad 3$$

$$T \rightarrow F \qquad \{\} \qquad 4$$

$$F \rightarrow num \qquad \{printf(num.lval);\} \qquad (5)$$

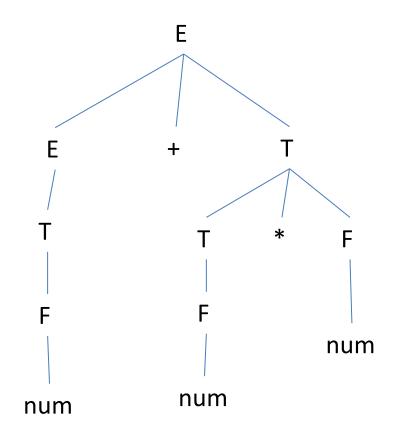
For input, 2 + 3 * 4

Output: 234*+



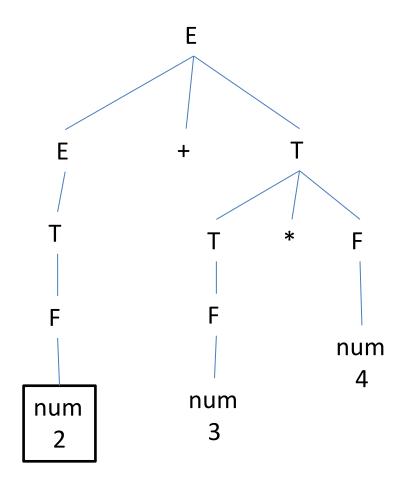
SDT to convert infix to postfix

$$E \rightarrow E + T$$
 {printf("+");}
 $E \rightarrow T$ {}
 $T \rightarrow T * F$ {printf("*");}
 $T \rightarrow F$ {}
 $F \rightarrow \text{num}$ {printf(num.lval);}



• SDT to convert infix to postfix

$$E \rightarrow E + T$$
 {printf("+");}
 $E \rightarrow T$ {}
 $T \rightarrow T * F$ {printf("*");}
 $T \rightarrow F$ {}
 $F \rightarrow \text{num}$ {printf(num.lval);}



SDT to convert infix to postfix

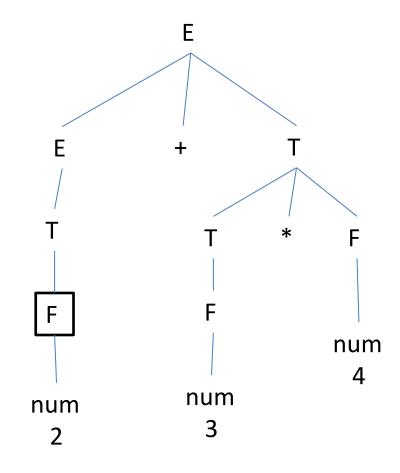
```
E \rightarrow E + T {printf("+");}

E \rightarrow T {}

T \rightarrow T * F {printf("*");}

T \rightarrow F {}

F \rightarrow \text{num} {printf(num.lval);}
```



SDT to convert infix to postfix

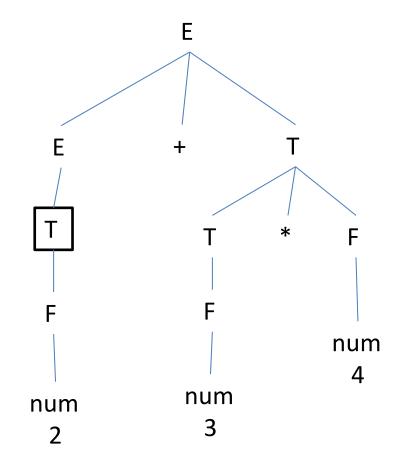
```
E \rightarrow E + T {printf("+");}

E \rightarrow T {}

T \rightarrow T * F {printf("*");}

T \rightarrow F {}

F \rightarrow \text{num} {printf(num.lval);}
```



SDT to convert infix to postfix

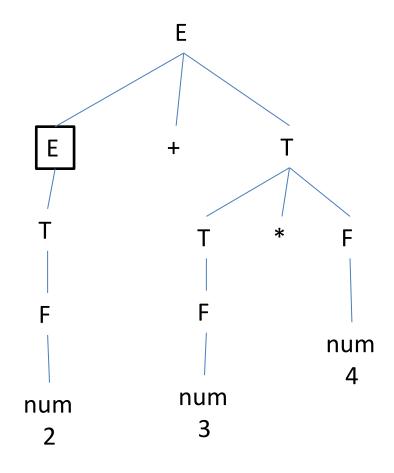
```
E \rightarrow E + T {printf("+");}

E \rightarrow T {}

T \rightarrow T * F {printf("*");}

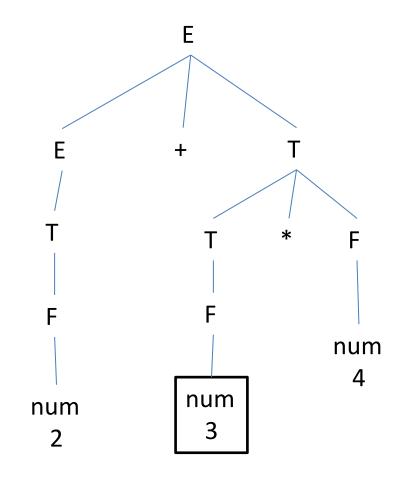
T \rightarrow F {}

F \rightarrow \text{num} {printf(num.lval);}
```



SDT to convert infix to postfix

$$E \rightarrow E + T$$
 {printf("+");}
 $E \rightarrow T$ {}
 $T \rightarrow T * F$ {printf("*");}
 $T \rightarrow F$ {}
 $F \rightarrow \text{num}$ {printf(num.lval);}



SDT to convert infix to postfix

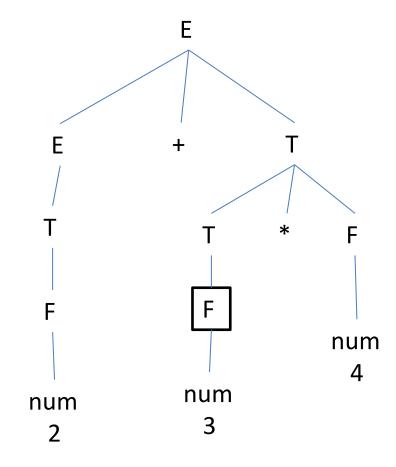
```
E \rightarrow E + T {printf("+");}

E \rightarrow T {}

T \rightarrow T * F {printf("*");}

T \rightarrow F {}

F \rightarrow \text{num} {printf(num.lval);}
```



SDT to convert infix to postfix

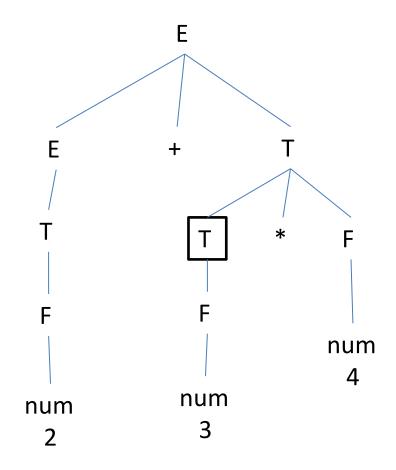
```
E \rightarrow E + T {printf("+");}

E \rightarrow T {}

T \rightarrow T * F {printf("*");}

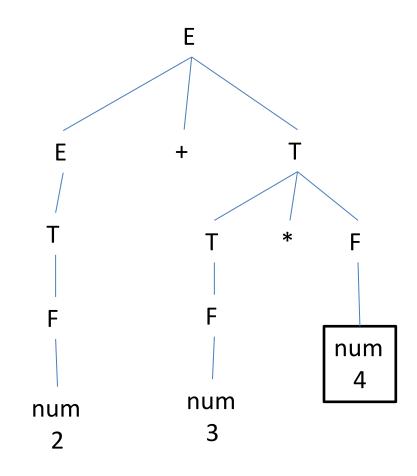
T \rightarrow F {}

F \rightarrow \text{num} {printf(num.lval);}
```



SDT to convert infix to postfix

$$E \rightarrow E + T$$
 {printf("+");}
 $E \rightarrow T$ {}
 $T \rightarrow T * F$ {printf("*");}
 $T \rightarrow F$ {}
 $F \rightarrow \text{num}$ {printf(num.lval);}



• SDT to convert infix to postfix

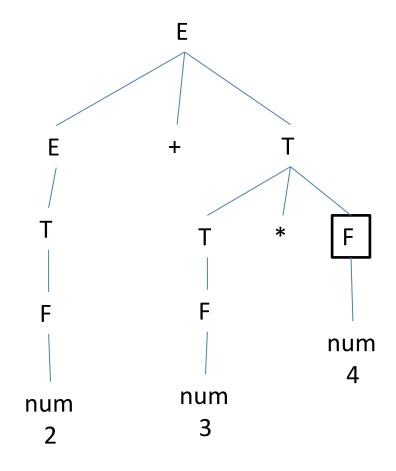
```
E \rightarrow E + T {printf("+");}

E \rightarrow T {}

T \rightarrow T * F {printf("*");}

T \rightarrow F {}

F \rightarrow \text{num} {printf(num.lval);}
```



SDT to convert infix to postfix

```
E \rightarrow E + T {printf("+");}

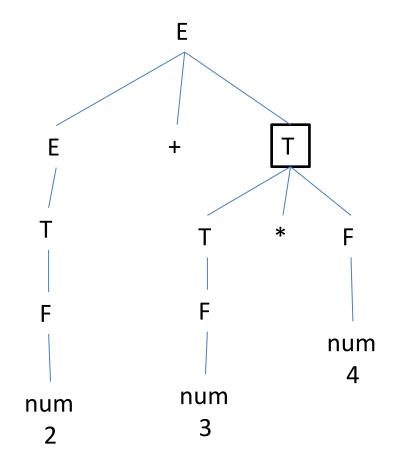
E \rightarrow T {}

T \rightarrow T * F {printf("*");}

T \rightarrow F {}

F \rightarrow \text{num} {printf(num.lval);}
```

For input, 2 + 3 * 4 Output: 2 3 4 *



• SDT to convert infix to postfix

```
E→E+T {printf("+");}

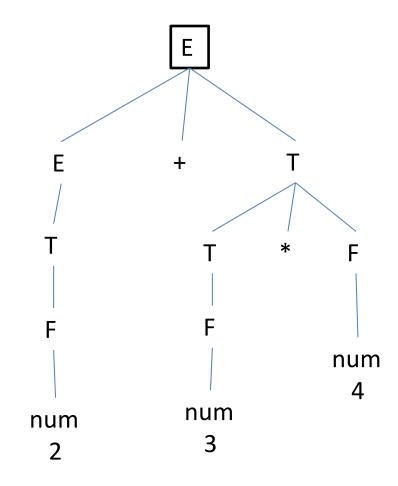
E→T {}

T→T*F {printf("*");}

T→F {}

F→ num {printf(num.lval);}
```

For input, 2 + 3 * 4 Output: 2 3 4 * +



SDT to convert infix to postfix

```
E \rightarrow E + T {printf("+");}

E \rightarrow T {}

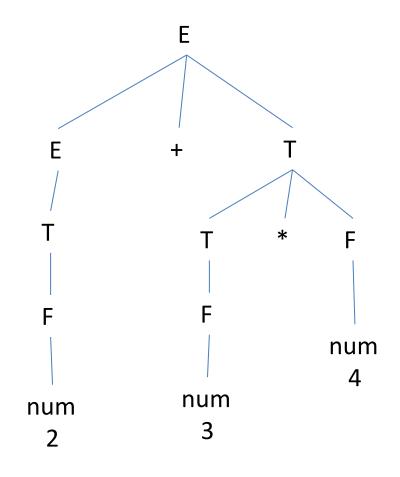
T \rightarrow T * F {printf("*");}

T \rightarrow F {}

F \rightarrow \text{num} {printf(num.lval);}
```

For input, 2 + 3 * 4

Output: 234*+



Example 5

SDT to build a syntax tree

Example 5

SDT to build a syntax tree

