Syntax Directed Definition and Syntax Directed Translation

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3. Difference between synthesized and inherited
4. SDT
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❑ Syntax Directed Definition

A CFG with attributes and rules is called a syntax-directed definition (SDD). The properties are linked to the grammar symbols in an extended CFG (i.e. nodes of the parse tree). The rules are associated with grammar production.

SDD = grammar + semantic rules

❑ Types of Attributes

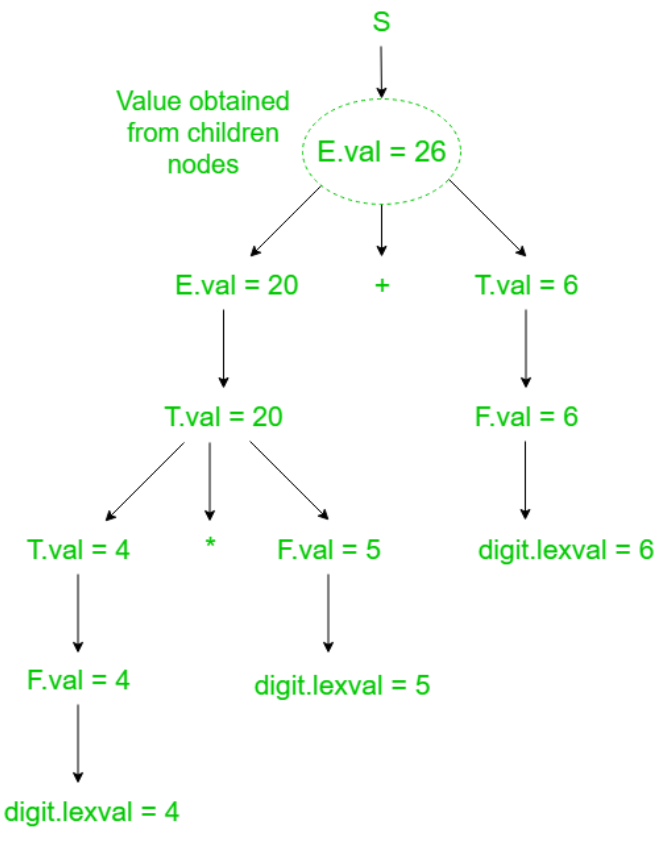
There are two types of attributes:
1. Synthesized Attributes
2. Inherited Attributes

1. Synthesized Attributes: These are those attributes which derive their values from their children's nodes i.e. value of synthesized attribute at node is computed from the values of attributes at children's nodes in parse tree.

Example: Consider the following grammar

Production	Semantic Actions
S --> E	Print(E.val)
E --> E_1 + T	E.val = E_1.val + T.val
E --> T	E.val = T.val
T --> T_1 * F	T.val = T_1.val * F.val
T --> F	T.val = F.val
F --> digit	F.val = digit.lexval

Solution:
Let us assume an input string 4 * 5 + 6 for computing synthesized attributes. The annotated parse tree for the input string is :



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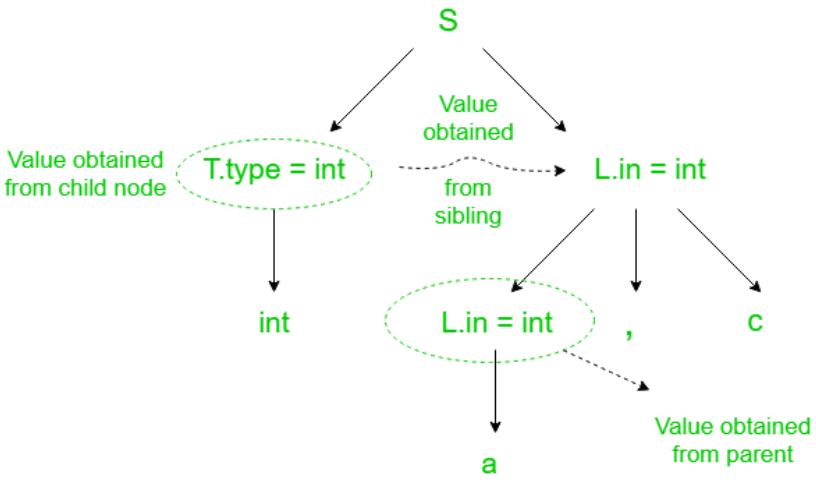
2. Inherited Attributes: These are the attributes which derive their values from their parent or sibling nodes i.e. value of inherited attributes are computed by value of parent or sibling nodes.

The SDD for the above grammar can be written as follow

Production	Semantic Actions
S --> T L	L.in = T.type
T --> int	T.type = int
T --> float	T.type = float
T --> double	T.type = double
L --> L_1 , id	L_1.in = L.in Enter_type(id.entry , L.in)
L --> id	Entry_type(id.entry , L.in)

Solution:

Let us assume an input string int a, c for computing inherited attributes. The annotated parse tree for the input string is:



❑ Difference between synthesized and inherited

S.NO	Synthesized Attributes	Inherited Attributes
1.	An attribute is said to be Synthesized attribute if its parse tree node value is determined by the attribute value at child nodes.	An attribute is said to be Inherited attribute if its parse tree node value is determined by the attribute value at parent and/or siblings' node.
2.	The production must have non-terminal as its head.	The production must have non-terminal as a symbol in its body.
3.	A synthesized attribute at node n is defined only in terms of attribute values at the children of n itself.	A Inherited attribute at node n is defined only in terms of attribute values of n's parent, n itself, and n's siblings.
4.	It can be evaluated during a single bottom-up traversal of parse tree.	It can be evaluated during a single top-down and sideways traversal of parse tree.
5.	Synthesized attributes can be contained by both the terminals or non-terminals.	Inherited attributes can't be contained by both, It is only contained by non-terminals.
6.	Synthesized attribute is used by both S-attributed SDT and L-attributed SDT.	Inherited attribute is used by only L-attributed SDT.
7.	EX:- E.val -> F.val E val ↑ F val	EX:- E.val = F.val E val ↓ F val

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❑ Syntax Directed Translation in Compiler Design

It refers to the translation of a string into an array of actions. This is done by adding an action to a rule of context-free grammar. It is a type of compiler interpretation.

SDT= grammar + semantic rules

SDT ensures a systematic and structured way of translating programs, allowing information to be processed bottom-up or top-down through the parse tree. This makes translation efficient and accurate, ensuring that every part of the input program is correctly transformed into its executable form.

SDT relies on three key elements:

1. Lexical values of nodes (such as variable names or numbers).
2. Constants used in computations.
3. Attributes associated with non-terminals that store intermediate results.

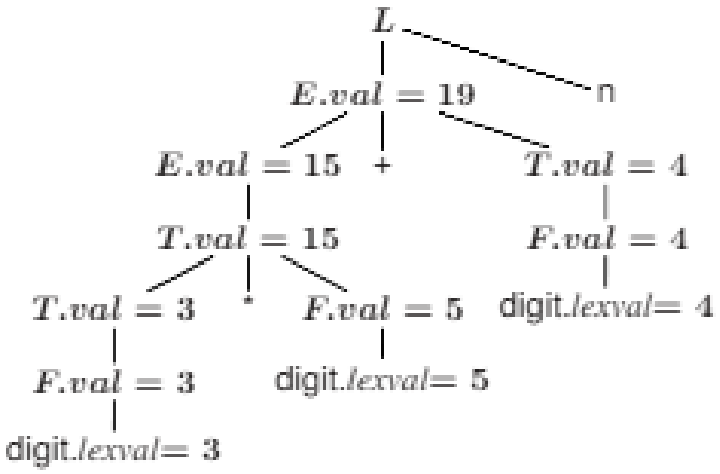
❑ Attributes of SDT:

S-attributed Translation

An SDD is S-attributed if the attributes of the node are synthesized attributes. To evaluate S-attributed SDD we can traverse the nodes of the parse tree in any bottom-up order. In S-attributed SDD the attributes are evaluated by applying post-order traversal. In postorder traversal, node N is evaluated when the traverser traverses node N for the last time.

PRODUCTION	SEMANTIC RULE
$L \to En$	$print(E.val)$
$E \to E_1 + T$	$E.val := E_1.val + T.val$
$E \to T$	$E.val := T.val$
$T \to T_1 * F$	$T.val := T_1.val * F.val$
$T \to F$	$T.val := F.val$
$F \to (E)$	$F.val := E.val$
$F \to$ digit	$F.val :=$digit.$lexval$

- **Example.** The above arithmetic grammar is an example of an S-Attributed Definition. The annotated parse-tree for the input 3*5+4n is:



Syntax Directed Definition and Syntax Directed Translation

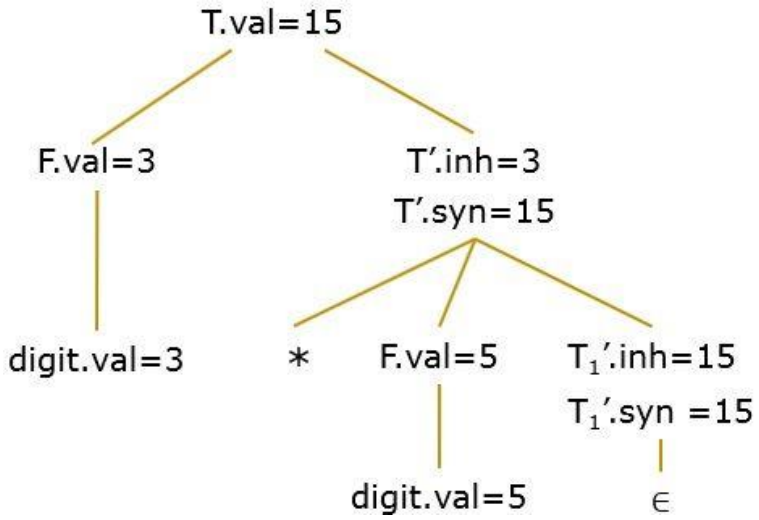
L-attributed Translation

An SDD is L-attributed if the attributes of nodes are either synthesized or inherited. Here we can traverse the parse tree strictly from left to right. This is because, in 'L-attributed translation', L signifies left-to-right traversing.

The SDD in the figure below is L-attributed:

Production	Semantic Rules
1) T -> F T'	T'.*inh* = F.*val* T.*val* = T'.*syn*
2) T' -> *FT_1'	T_1'.*inh* = T'.*inh* * F.*val* T'.*syn* = T_1'.*syn*
3) T' -> ∈	T'.*syn* = T'.*inh*
4) F -> digit	F.*val* = digit.*val*

The Annotated parse tree for the L-attributed SDD above is as follow:



To evaluate the L-attributed SDD, start evaluating the following order:

- The value of the inherited attribute.
- Then the value of synthesizing attributes.

❑ Attributes of SDT: L-attribute and S-attribute

S- attributed SDD	L- attributed SDD
A SDD that uses only synthesized attribute is called S-attributed SDD. Ex: A → BCD A.i = B.i A.i = C.i A.i = D.i	A SDD that uses both synthesized and inherited attribute is called l-attributed SDD. L-attributed SDD but each inherited attribute is restricted to inherit from parent or left siblings only. A → BCD C.i = A.i C.i = B.i C.i = D.i
Semantic actions are always placed at right end of the production.	Semantic action is placed anywhere or RHS of the production.
Attributes are evaluated with bottom to parent	Attributes are evaluated by traversing parse tree depth first, left to right.

Syntax Directed Definition and Syntax Directed Translation

❑ SDD v/s SDT Scheme

Syntax Directed Definition	Syntax Directed Translation
It is a context-free grammar where attributes and rules are combined and associated with grammar symbols and productions, respectively.	It refers to the translation of a string into an array of actions. This is done by adding an action to a rule of context-free grammar. It is a type of compiler interpretation.
SDD: Specifies the values of attributes by associating semantic rules with the productions.	SDT: Embeds program fragments (also called semantic actions) within production bodies.
E → E + T { E.val := E1.val + T.val }	E → E + T { print('+'); }
Always written at the end of the body of production.	The position of the action defines the order in which the action is executed (in the middle of production or at the end).
More Readable	More Efficient
Used to specify the non-terminals.	Used to implement S-Attributed SDD and L-Attributed SDD.
Specifies what calculation is to be done at each production.	Specifies what calculation is to be done at each production and at what time they must be done.
Left to right evaluation.	Left to right evaluation.
Used to know the value of non-terminals.	Used to generate Intermediate Code.

❑ Problems on SDT:

Problem - 1 : Consider the grammar:

Grammar	Rules
S->S#A A->A&B B->id	S.val = S.val * A.val A.val = A.val + B.val B.val = id.lval

Given string w = 5 # 3 & 4. Find output.

Syntax Directed Definition and Syntax Directed Translation

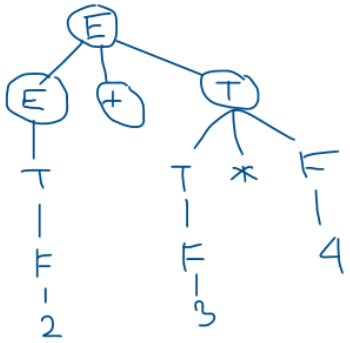
Problem -2 : The following context-free grammar (CFG) defines an arithmetic expression with addition (+) and multiplication (*):

```
E -> E + T      { E.val = E.val + T.val }
E -> T          { E.val = T.val }
T -> T * F      { T.val = T.val * F.val }
T -> F          { T.val = F.val }
F -> INTLIT     { F.val = INTLIT.lexval }
```

Let's evaluate the expression: S = 2 + 3 * 4

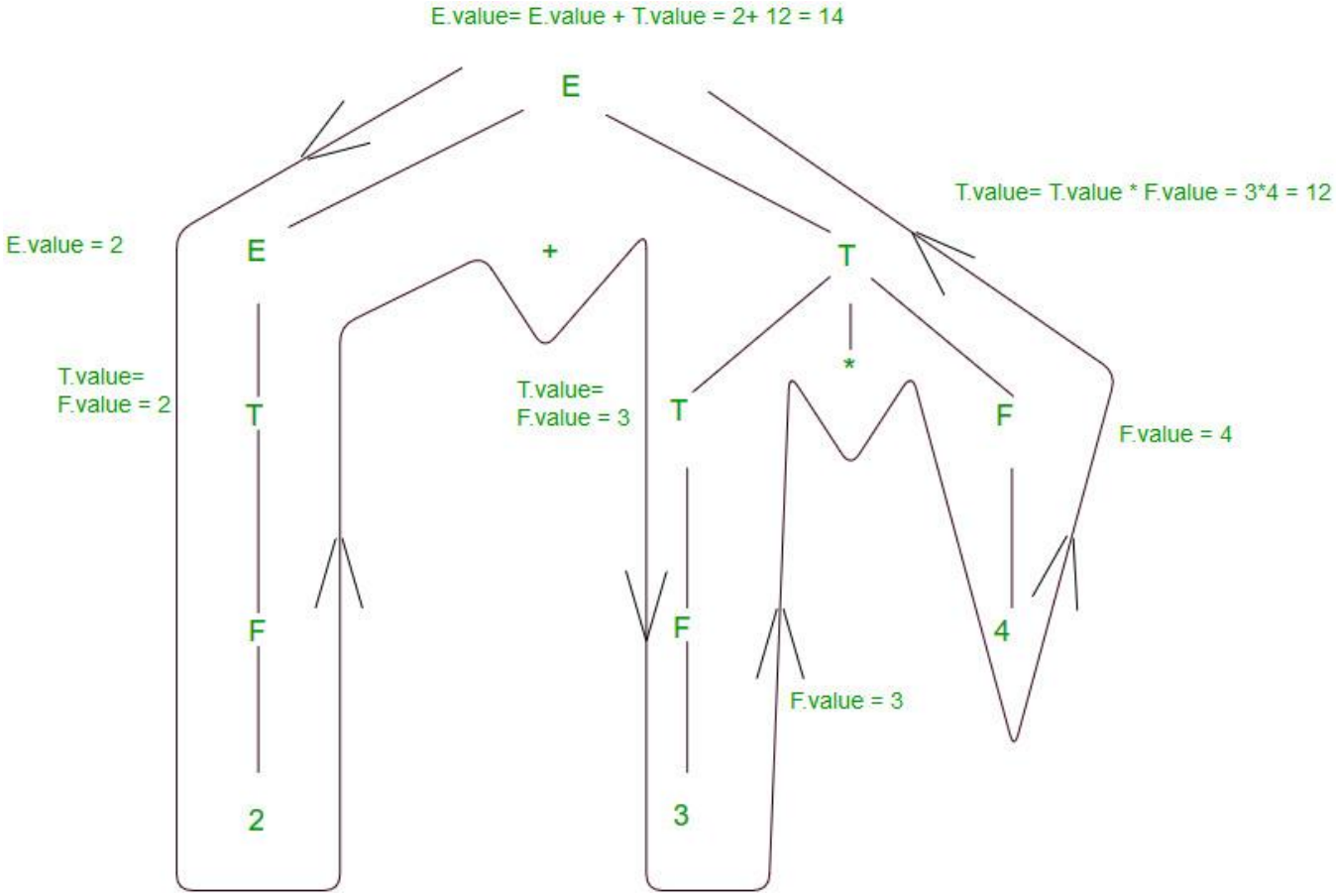
Solution: Step 1: Build the Parse Tree

The parse tree for 2 + 3 * 4 is structured like this:



Step 2: Apply Translation Rules (Bottom-Up Evaluation)

We evaluate the expression step by step in a bottom-up manner (from leaves to root)

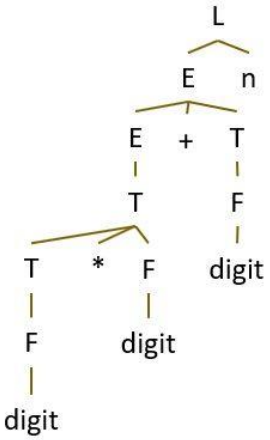


Syntax Directed Definition and Syntax Directed Translation

Problem -3 :. Consider the SDD provided in the figure below. Here we can see the production rules of grammar along with the semantic actions. And the input string provided by the lexical analyzer is 3 * 5 + 4 n.

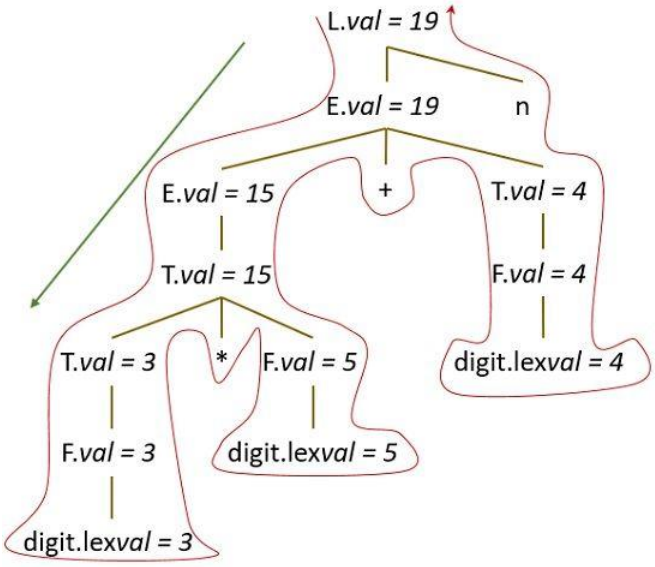
Production	Semantic Rules
1) L -> E **n**	L.*val* = E.*val*
2) E -> E_1 + T	E.*val* = E_1.*val* + T.*val*
3) E -> T	E.*val* = T.*val*
4) T -> T_1 * F	T.*val* = T_1.*val* x F.*val*
5) T -> F	T.*val* = F.*val*
6) F -> (E)	F.*val* = E.*val*
7) F -> digit	F.*val* =digit.*lexval*

To perform SDT the first thing we must do is to create a parse tree with the provided production and lexical input.



Parse Tree for Input String 3 * 5 + 4 n

The next step is to create an annotated parse tree. So, we will traverse the parse tree from top to bottom. Then add the semantic rule to evaluate the attribute of each node. Thus, you can evaluate the output for the given input string as you can see in the image below.



Annotated Parse Tree for Input String 3 * 5 + 4 n

Syntax Directed Definition and Syntax Directed Translation

Problem -4 : Consider the following grammar and the semantic actions to support the inherited type declaration attributes. Let *X*1, X2, X3, *X*4, *X*5, and *X*6 be the placeholders for the non-terminals D, T, L or L1 in the following table:

Production Rule	Semantic Action
D → T L	*X*1.type = *X*2.type
T → int	T.type = int
T → float	T.type = float
L → LI , id	*X*3.type = *X*4.type addType(id.entry, *X*5.type)
L → id	addType(id.entry, *X*6.type)

Which one of the following are the appropriate choices for *X*1, *X*2, *X*3 and *X*4?

(A) X1=L, X2=T, X3=L1, X4=L
(B) X1=T, X2=L, X3=L1, X4=T
(C) X1=L, X2=L, X3=L1, X4=T
(D) X1=T, X2=L, X3=T, X4=L1

Problem - 5 : Consider the grammar:-

Grammar	Rules
E->E # T	E.val=E.val*T.val
E->T	E.val=T.val
T->T&F	T.val=_____
T->F	T.val=F.val
F->digit	F.val=digit.val

if the expression **w = 8 # 12 & 4 # 16 & 12 # 4 & 2** is evaluated to 512 then which of the following is correct replacement for blank.

1. T.val = T.val * F.val
2. T.val = T.val + F.val
3. T.val = T.val - F.val
4. none