Semantic Analysis

- Ultimate goal: generate machine code.
- Before we generate code, we must collect information about the program:
- Front end
  - scanning (recognizing words) CHECK
  - parsing (recognizing syntax) CHECK
  - semantic analysis (recognizing meaning)
    - There are issues deeper than structure. Consider:

```
int func (int x, int y);
int main () {
        int list[5], i, j;
        char *str;
        j = 10 + 'b';
        str = 8;
        m  = func("aa", j, list[12]);
        return 0;
}
```

This code is syntactically correct, but will not work. What problems are there?

Semantic analysis

- Collecting type information may involve "computations"
  - What is the type of x+y given the types of x and y?
- Tool: attribute grammars
  - CFG
  - Each grammar symbol has associated attributes
  - The grammar is augmented by rules (semantic actions) that specify how the values of attributes are computed from other attributes.
  - The process of using semantic actions to evaluate attributes is called syntax-directed translation.
  - Examples:
    - Grammar of declarations.
    - Grammar of signed binary numbers.

Attribute grammars

Example 1: Grammar of declarations

Production	Semantic rule
$D \rightarrow T\ L$	L.in = T.type
$T \rightarrow$ int	T.type = integer
$T \rightarrow$ char	T.type = character
$L \rightarrow L_1$, id	L_1.in = L.in
	addtype (id.index, L.in)
$L \rightarrow$ id	addtype (id.index, L.in)

Attribute grammars

Example 2: Grammar of signed binary numbers

Production	Semantic rule

$N \rightarrow S\ L$	if (S.neg)
	print('-');
	else print('+');
	print(L.val);

$S \rightarrow +$	S.neg = 0
$S \rightarrow -$	S.neg = 1
$L \rightarrow L_1, B$	$L.val = 2*L_1.val+B.val$
$L \rightarrow B$	L.val = B.val
$B \rightarrow 0$	$B.val = 0*2^0$
$B \rightarrow 1$	$B.val = 1*2^0$

Attribute grammars

Example 3: Grammar of expressions
Creating an AST

The attribute for each non-terminal is a node of the tree.

darek non-terminal mate je attribute hase is a node of the tree.

Production	Semantic rule
$E \rightarrow E_1+E_2$	E.node = new PlusNode(E_1.node,E_2.node)
$E \rightarrow$ num	E.node = num.yylval
$E \rightarrow (E_1)$	E.node = E_1.node

Syntax-Directed Definitions and Translation Schemes

- When we associate semantic rules with productions, we use two notations:
  - **Syntax-Directed Definitions**
  - **Translation Schemes**
- **Syntax-Directed Definitions:**
  - give high-level specifications for translations
  - hide many implementation details such as order of evaluation of semantic actions.
  - We associate a production rule with a set of semantic actions, and we do not say when they will be evaluated.
- **Translation Schemes:**
  - indicate the order of evaluation of semantic actions associated with a production rule.
  - In other words, translation schemes give a little bit information about implementation details.

Syntax-Directed Definitions and Translation Schemes

- With each production in a grammar, we give semantic rules or *actions*, *which describe* how to compute the attribute values associated with each grammar symbol in a production. The attribute value for a parse node may depend on information from its children nodes below or its siblings and parent node above.
- Evaluation of these semantic rules (using SDT one can perform following with parser):
  - may generate intermediate codes
  - may put information into the symbol table
  - may perform consistency check like type checking, parameter checking etc…
  - may issue error messages
  - may build syntax tree
  - in fact, they may perform almost any activities.
- Procedure :

1) Input – Grammer
2) Output – Attached semantic rules

iscesa

darek production je pan grammar ma hoi... aena related nu semantic actions or rules apde apiye 6e....
je pan describe karse ke tamare kevi ritna compute karvanu 6e attribute values ne je pan associated hoi with each grammar symbol in the production.

je attribute value hoi 6e for the parse node => will depend on the information from its children nodes ke pan aena below hoi ka to aena parent nodes je ke je to aena above hoi.

Syntax-Directed Definitions

1.darek grammar symbol ne associate karo with the set of attributes
2. this set of attributes for a grammar symbol => 2 sets .= synthesized and inherited
3.darek production rule hoi it is associated with a set of semantic rules

- A syntax-directed definition is a generalization of a context-free grammar in which:
  - Each grammar symbol is associated with a set of attributes.
  - This set of attributes for a grammar symbol is partitioned into two subsets called **synthesized** and **inherited** attributes of that grammar symbol.
  - Each production rule is associated with a set of semantic rules.
- *Semantic rules* set up dependencies between attributes which can be represented by a *dependency graph*.
- This *dependency graph* determines the evaluation order of these semantic rules.
- Evaluation of a semantic rule defines the value of an attribute. But a semantic rule may also have some side effects such as printing a value.

semantic rules su kare 6e?= set up kare 6e dependencies attributes ....kevi ritna represent karis ?= dependency graph
aa dependency graph =>su karse ?= determine karse ...su determine karse ?= evalution order ...kona evaluation order ne ?= semantic rules
semantic rules na evaluation na pachi su thase?= vlaue of attribute khabar padse...

pan amuk vkht to aa semantic rules na kaik to side effects pan hoie e that is ke ae to print karse ae value ne

Annotated Parse Tree

ek aevo parse tree ke jya tamne values of the attribute darek node na upar mde = annotated parse tree.

- A parse tree showing the values of attributes at each node is called an **annotated parse tree**.
- The process of computing the attributes values at the nodes is called **annotating** (or **decorating**) of the parse tree.
- The order of these computations depends on the dependency graph induced by the semantic rules.

ae vadi process ke jya tame attribute vlaues ne compute karo 6o for each node aene kehvay = annotating , decorating

ae computations no order je 6e ae to depend kare 6e ....kona upar ?= dependency graph na upar ...kevo depedency graph?= je semantic rules thi induce karvama ayo 6e.

- An attribute is said to be **synthesized** if its value at a parse tree node is determined by the attribute values at the child nodes.
- An attribute is said to be **inherited** if its value at a parse tree node is determined by the attribute values of the parent and/or siblings of that node.

Example

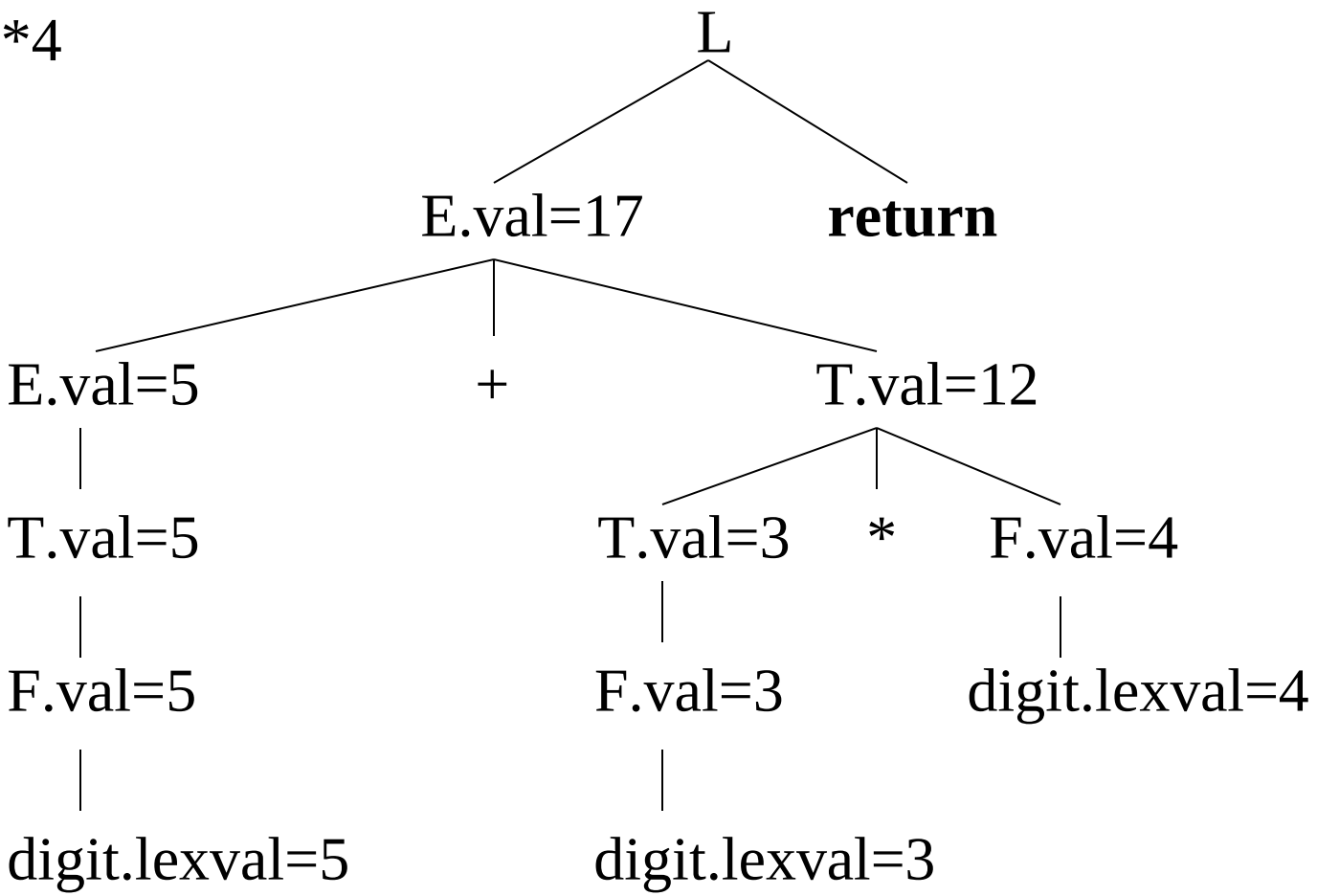
Production	**Semantic Rules**
L → E **return**	print(E.val)
E → E_1 + T	E.val = E_1.val + T.val
E → T	E.val = T.val
T → T_1 * F	T.val = T_1.val * F.val
T → F	T.val = F.val
F → (E)	F.val = E.val
F → **digit**	F.val = **digit**.lexval

- Symbols E, T, and F are associated with a synthesized attribute *val*.
- The token **digit** has a synthesized attribute *lexval* (it is assumed that it is evaluated by the lexical analyzer).
- Terminals attributes calculated at the time of lexical analysis phase

annotated parse trees na terminal attributes ni values are been calculated at the time of the lexical analysis phase.

Annotated Parse Tree -- Example

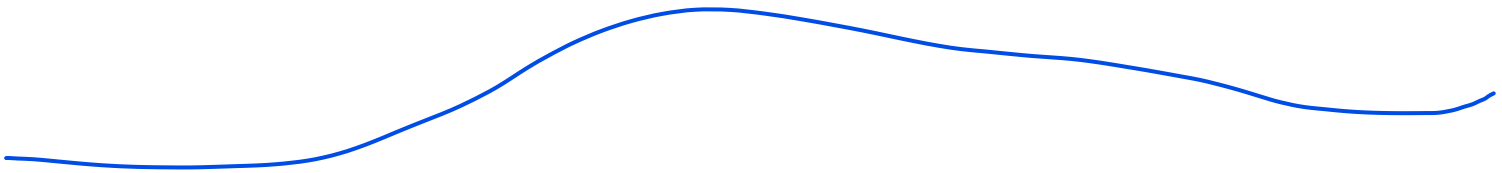
Input: 5+3*4



Example - Inherited Attributes

Production	**Semantic Rules**
$D \rightarrow T\ L$	L.in = T.type
$T \rightarrow$ **int**	T.type = integer
$T \rightarrow$ **real**	T.type = real
$L \rightarrow L_1$ **id**	L_1.in = L.in, addtype(**id**.entry,L.in)
$L \rightarrow$ **id**	addtype(**id**.entry,L.in)

- Symbol T is associated with a synthesized attribute *type*.
- Symbol L is associated with an inherited attribute *in*.



Translation Schemes

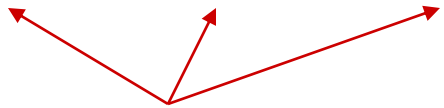
- In a syntax-directed definition, we do not say anything about the evaluation times of the semantic rules (when the semantic rules associated with a production should be evaluated?).

what it is ? = context free grammar 6e...

- A **translation scheme** is a context-free grammar in which:
  - attributes are associated with the grammar symbols and
  - semantic actions enclosed between braces { } are inserted within the right sides of productions.

attributes are associated kona jode with the grammar symbols

- *Ex:* $A \rightarrow \{ \ldots \}\ X\ \{ \ldots \}\ Y\ \{ \ldots \}$



Semantic Actions

semantic actions => enclosed with the braces.... they are inserted to the right side of the production.

Translation Schemes

- When designing a translation scheme, some restrictions should be observed to ensure that an attribute value is available when a semantic action refers to that attribute.
- These restrictions (motivated by L-attributed definitions) ensure that a semantic action does not refer to an attribute that has not yet computed.

translation schemes ----------> semantic action
syntax-directed definaitons ----------> semantic rule

- In translation schemes, we use *semantic action* terminology instead of *semantic rule* terminology used in syntax-directed definitions.
- The position of the semantic action on the right side indicates when that semantic action will be evaluated.

position of the semantic action => su darshave 6e ke kyare aene evaluate karvani jarur 6e.

ahiya to thodak restrictions 6e ke .... attribute value available hovi joie ...kyare jyare pan tamaro semantic action ae attribute ne refer karva mange ne tyare ....aa restrictions kona thi motivated 6e ? L-attributed definations thi....

L-attributed definitions thi su avse ?= ensure karse ke tamaro semantic rule aeva koi attribute ne refer nathi karto ke jeni haji to value pan compute nathi thai.