03/31/2010

Recitation #10

Administrative

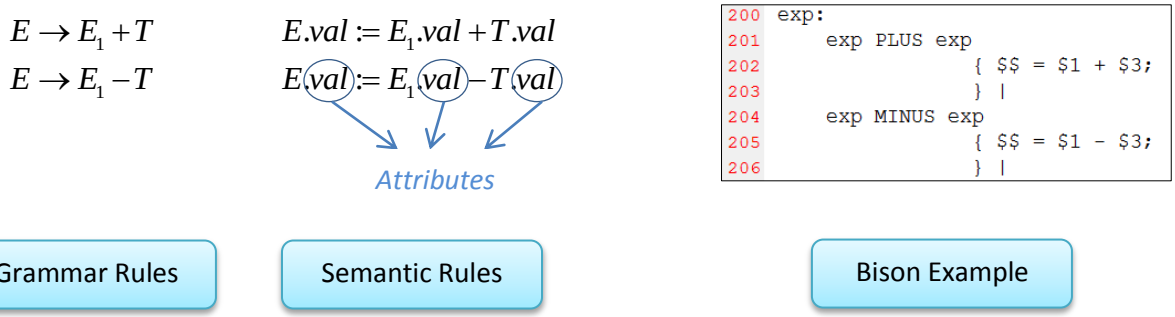
- Assignment 4 – Late Penalty changed
  - 5% off for each day late → up to 4 days late, i.e. 20% off when submitted on Friday
  - If you submitted before the deadline, WebCourses doesn't let you submit again → send e-mail with attached files
  - Any more questions on assignment?
- Final Project is coming up
  - Dr. Hughes will discuss in class
  - Will build on and extend Assignment 4

SLR Parser - Worksheet

- Continue from last week and finish worksheet
- Review some terminology and CLOSURE and GOTO functions
- See notes for Recitation #9 and solution for worksheet

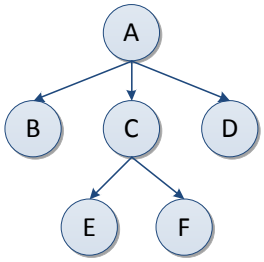
Syntax-Directed Definition

- Associate information with language construct by **attaching attributes** to grammar symbols
- Attributes can represent e.g. data types, definition scope, function visibility etc.
- Syntax-Directed Definition (SDD) specifies values of attributes by associating **semantic rules** with the grammar productions, e.g.



- **Bison/Yacc has built-in notion of attributes**, referred to as $$, $1 → should be familiar with them from Assignment 4
- **Annotated Parse Tree:**
  - Adds attributes to nodes
  - Also called attributed or decorated parse tree
  - Depth-first search tree traversal
  - Each step in tree traversal performs one of these steps: Process node data (N), traverse child n (C..)
  - Three common traversal types:

1. *Pre-order traversal* (NC..) : Each node is visited before its children are visited, e.g. A, B, C, E, F, D
2. *Post-order traversal* (C..N) : The children of a node are visited before the node itself, e.g. B, E, F, C, D, A
3. *Inorder traversal* : Makes only sense in binary tree. Traverse left subtree, before node (N), then traverse right subtree.



- How do we determine **the order of evaluation of the attributes**?
  - Build parse tree
  - Create dependency graph between attributes
  - Find a topological sort on that graph and evaluate attributes in that order

Synthesized Attributes

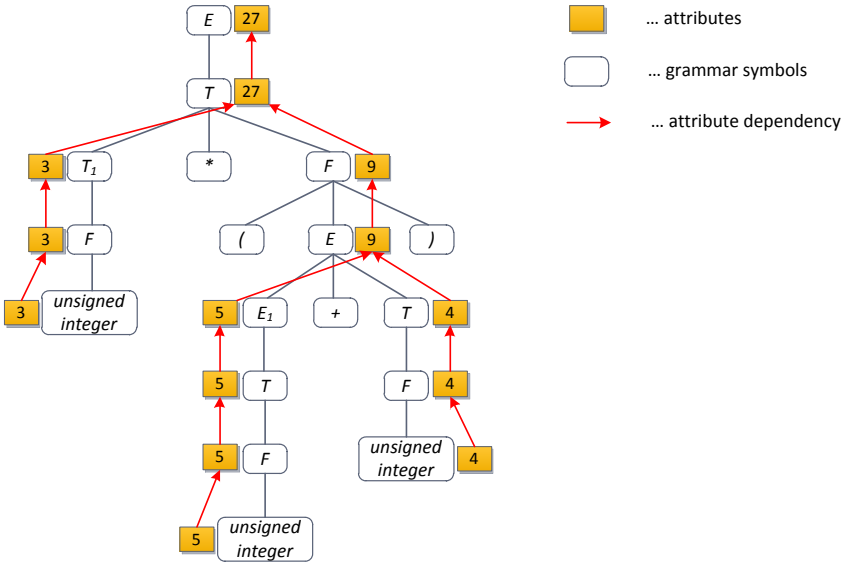
- Attributes are synthesized when they are defined at a node labeled A using attributes of the node and its children
- The usual synthesized attributes **start as token values**, which are the leaves of the parse tree → Terminals are only allowed to have synthesized attributes
- Everything on right-hand side of grammar rule are children non-terminals and terminals in parse tree
- In Bison, each action synthesizes the value of its resulting symbol ($$) from the values of the symbols on the *right-hand side of the rule, e.g. $1, $2 etc.*
- In bottom-up parser with synthesized attributes, information passes from leaves to root

```
200 exp:
201     exp PLUS exp
202                 { $$ = $1 + $3;
203                 } |
204     exp MINUS exp
205                 { $$ = $1 - $3;
206                 } |
```

- **S-attributed SDD**
  - SDD with only synthesized attributes
  - Evaluates up the tree (typically post-order traversal)
  - Example:

$E \to E_1 + T$	$E.val := E_1.val + T.val$
$E \to E_1 - T$	$E.val := E_1.val - T.val$
$E \to T$	$E.val := T.val$
$T \to T_1 * F$	$T.val := T_1.val * F.val$
$T \to T_1 / F$	$T.val := T_1.val / F.val$
$T \to F$	$T.val := F.val$
$F \to -F_1$	$F.val := -F_1.val$
$F \to (E)$	$F.val := E.val$
$F \to \text{id}$	$F.val := \text{id}.entry$
$F \to \text{unsigned\_integer}$	$F.val := \text{unsigned\_integer}.val$

  - Annotated Parse Tree for string **3 * (5 + 4)**:



Inherited Attributes

- Information sometimes needs to pass from parent to children
- Attributes are inherited when they are defined at node labeled A using attributes of the node, its parent and its children.
- **When can they be important**?
    - Example (in Bison):

```
1  declaration:
2      class type namelist
3      ;
4
5  class:
6      GLOBAL            { $$ = 1; } |
7      LOCAL             { $$ = 2; }
8      ;
9
10 type:
11     REAL              { $$ = 1; } |
12     INTEGER           { $$ = 2; }
13     ;
14
15 namelist:
16     NAME              { mksymbol($0, $-1, $1); } |
17     namelist NAME     { mksymbol($0, $-1, $2); }
18     ;
```


    - It would be useful to have class and type available in the actions for 'namelist', e.g. for error checking and entering in symbol table
    - Bison allows access to symbols on its internal stack (to the left of current rule)
    - Inherited attributes can be source of hard-to-find bugs → Make sure correct symbols always precede 'namelist' in new grammar rules

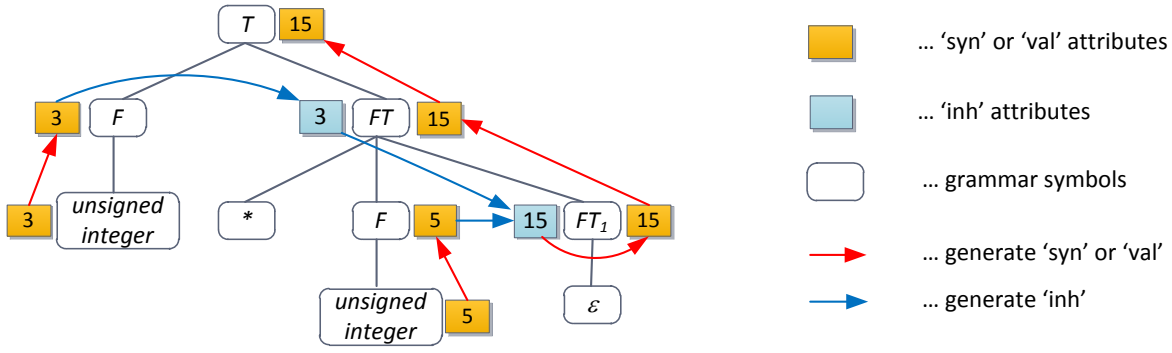
- **L-attributed SDD**
    - SDD with mixed synthesized and inherited attributes
    - Can be evaluated left-to-right and depth-first

- Example (Expression grammar that is right-recursive and left factored):

(1)	$T \to F \;\; FT$	$FT.inh := F.val; T.val := FT.syn$
(2)	$FT \to *F \;\; FT_1$	$FT_1.inh := FT.inh * F.val; FT.syn := FT_1.syn$
(3)	$FT \to \varepsilon$	$FT.syn = FT.inh$
(4)	$F \to \text{unsigned\_integer}$	$F.val := \text{unsigned\_integer}.val$

- The following **explanation** is taken from the [Aho] book pages 308 – 309
- The semantic rules are based on the idea that the left operand of the operator * is inherited.
- The head FT of the production $FT \to *F \;\; FT_1$ inherits the left operand of * in the production body
- E.g. given a term x * y * z, the root of the subtree for * y * z inherits x. Then, the root of the subtree for *z inherits the value of x * y, and so on. Once all the factors have been accumulated, the result is passed back up the tree using synthesized attributes

- Annotated Parse Tree for string **3 * 5**:



- Leftmost leaf in the parse tree has value 3 from the lexical analyzer
- Its parent is for production (4), only semantic rule takes value 3
- At the second child of the root, the inherited attribute $FT.inh$ is defined by the rule $FT.inh := F.val$ associated with production (1). Thus, the left operand, 3, for the * operand is passed from left to right across the children of the root
- The production (2) applies at node FT. The inherited attribute $FT_1.inh$ is defined by the rule $FT_1.inh := FT.inh * F.val$
- With $FT_1.inh := 3$ and $F.val := 5$, we get $FT_1.inh := 15$
- At the lower node for FT_1, production (3) applies. The semantic rule $FT_1.syn = FT_1.inh$ defines $FT_1.syn := 15$
- The syn attributes at the nodes for FT pass the value 15 up the tree to the node for T, where $T.val := 15$

Bigger Example:

$E \to T \;\; TT$	$TT.inh := T.val; E.val := TT.syn$
$TT \to +T \;\; TT_1$	$TT_1.inh := TT.inh + T.val; TT.syn := TT_1.syn$
$TT \to -T \;\; TT$	$TT_1.inh := TT.inh - T.val; TT.syn := TT_1.syn$
$TT \to \varepsilon$	$TT.syn := TT.inh$
$T \to F \;\; FT$	$FT.inh := F.val; T.val := FT.syn$
$FT \to *F \;\; FT_1$	$FT_1.inh := FT.inh * F.val; FT.syn := FT_1.syn$
$FT \to /F \;\; FT_1$	$FT_1.inh := FT.inh / F.val; FT.syn := FT_1.syn$
$FT \to \varepsilon$	$FT.syn = FT.inh$
$F \to -F_1$	$F.val := -F_1.val$
$F \to (E)$	$F.val := E.val$
$F \to \text{id}$	$F.val := \text{id}.entry$
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- Annotated Parse Tree for string **3 * (5 + 4)**: