Parsing and Parse Trees

Lecture 11

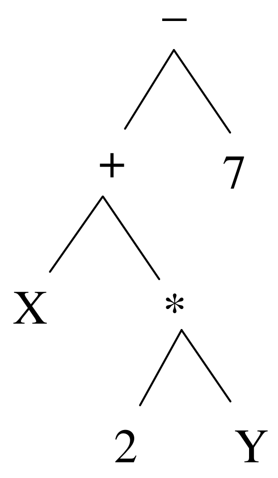
- The previous lecture looked at evaluating an expression while parsing it. This lecture looks at turning an expression or sentence of a formal language into a parse tree.
- This is what most compilers do as an intermediate step towards compiling a program.
- The parse tree can then be processed. We'll see how to evaluate an expression from its parse tree.

Parse Trees

- A parse tree is a tree structure representing sentences or expressions of a formal language that mirrors the grammar of that language, as defined by its BNF.
- For example, the parse tree for the expression

$$X + 2*Y - 7$$

would be the following.



Arithmetic Expressions

- We're going to see how to generate the parse tree for an arithmetic expression, as defined in the previous lecture. Here's the BNF again.

```
<expression> ::=   <term> |
                   <expression> + <term> |
                   <expression> – <term>

<term>       ::=   <factor> |
                   <term> * <factor> |
                   <term> / <factor>

<factor>     ::=   <number> | ( <expression> )
```

Parse Trees in C++

- Here's the type declaration for a parse tree for arithmetic expressions.
- The leaves of the tree (nodes with no sub-trees) are always numbers. Other nodes comprise an operator and two operands, where the operands are themselves trees.

```
class TreeNode {
    public:
        bool isLeaf;     //true for leaf node
        int number;      //filled for leaf node, else
        TreeNode* leftTree;  //operand 1 is another tree
        TreeNode* rightTree; //operand 2 is another tree
        char op;         // +, -, * or /
    };

typedef TreeNode* TreePtr;
```

Access Routines for Parse Trees I

- We assume that we have the access routines to handle the expression string as in the last lecture (see slides 10.16 – 10.18).
- We also assume the same routines to access the parse tree:

```
bool isLeafNode (TreePtr tree);
//returns true if tree points to leaf node

int leafValue (TreePtr tree);
//returns number at leaf node

char nodeOp (TreePtr tree);
//returns operator (+,-,*,/) at tree node

TreePtr leftOf (TreePtr tree);
//returns pointer of left sub-tree

TreePtr rightOf (TreePtr tree);
//returns pointer of right sub-tree
```

Access Routines for Parse Trees II

- In addition, we have the following two access procedures for building the parse tree and its leaves.

```
TreePtr buildLeaf (int number) {
    TreePtr newNode;

    newNode = new TreeNode;
    newNode->isLeaf = true;  //this is a leaf node
    newNode->number = number;
    newNode->leftTree = NULL;   //empty left tree
    newNode->rightTree = NULL;  //empty right tree
    newNode->op = '\0';         //no operator
    return newNode;
}
```

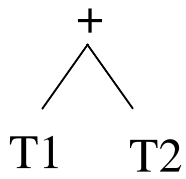
Access Routines for Parse Trees III

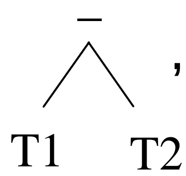
- In addition, we have the following two access procedures for building the parse tree and its leaves.

```
TreePtr buildNode (TreePtr op1,   //left operand tree
                   TreePtr op2,   //right operand tree
                   char op) {
    TreePtr newNode;

    newNode = new TreeNode;
    newNode->isLeaf = false;   //this is NOT a leaf node
    newNode->leftTree = op1;
    newNode->rightTree = op2;
    newNode->op = op;
    newNode->number = 0;       //empty number field
    return newNode;
}
```

From Expressions to Trees

- The functions that turn an arithmetic expression into a parse tree are much like the procedures in the previous lecture for evaluating an expression.
- To generate the parse tree T1 for an expression E, this is what you do.
  - Parse the next term in E, and let T1 be the resulting tree.
  - While the next character in E is an operator ("+" or "–"),
    - Read past the operator.
    - Parse the next term in E, giving tree T2.
    - Let T1 be either 

or 

, depending on the operator.

Parsing an Expression

- Here's the C++ code.

```
void parseExpression (string& expression,
                              TreePtr& expTree) {
  TreePtr tempTree;
  char op;

  parseTerm (expression, expTree);
  while ((notEmpty(expression)) &&
         ((nextChar(expression)=='+') ||
          (nextChar(expression)=='-'))){
      op = getNextChar(expression);
      parseTerm(expression, tempTree);
      expTree = buildNode(expTree, tempTree, op);
  }
}
```

Parsing a Term

- Here's the C++ code for parsing a term. No surprises here.

```
void parseTerm (string& expression,
                          TreePtr& expTree) {
  TreePtr tempTree;
  char op;

  parseFactor (expression, expTree);
  while ((notEmpty(expression)) &&
        ((nextChar(expression)=='*') ||
         (nextChar(expression)=='/'))){
     op = getNextChar(expression);
     parseFactor (expression, tempTree);
     expTree = buildNode(expTree, tempTree, op);
  }
}
```

Parsing a Factor

- Here's the code for parsing a factor. Again, no surprises.

```
void parseFactor (string& expression,
                          TreePtr& expTree) {

  if (notEmpty(expression) && (nextChar(expression)!='('))
     expTree = buildLeaf(getNum(expression));
  else {
     getNextChar(expression);                  // skip '('
     parseExpression(expression, expTree);
     getNextChar(expression);                  // skip ')'
  }
}
```

Evaluating a Parse Tree

- Here is the routine for evaluating an arithmetic expression from its parse tree.

```
int evalTree (TreePtr expTree) {
  int result;

  if (isLeafNode(expTree))
      result = leafValue(expTree);
  else {
      switch (nodeOp(expTree)) {
          case '+':
              result = evalTree(leftOf(expTree)) + evalTree(rightOf(expTree));
              break;
          case '-':
              result = evalTree(leftOf(expTree)) - evalTree(rightOf(expTree));
              break;
          case '*':
              result = evalTree(leftOf(expTree)) * evalTree(rightOf(expTree));
              break;
          case '/':
              result = evalTree(leftOf(expTree)) / evalTree(rightOf(expTree));
              break;
          default:
              result = 0;
              cout << "Error in evaluating expression tree\n";
      }
  }
  return result;
}
```

Printing the Tree

- Here is the routine to print the tree in console window.

```
void printTree(TreePtr expTree) {
     if (isLeafNode(expTree))
          cout << leafValue(expTree) << endl;
     else {
          cout << nodeOp(expTree) << endl;
          printTree(leftOf(expTree));
          printTree(rightOf(expTree));
     }
}
```

100*(3+4) - 10*(8/2)