Object-oriented design

- Goal: construct a representation for program.
  - Identify and encapsulate information associated with different aspects of a program through C++ classes.
  - Identify generalization and specialization relationship among various classes and represent them.
    Use inheritance to represent them.
- Approach:
  - Construct an **intermediate representation** of program by constructing a **parse tree**..
    What is a parse tree?
  - Represent nodes of a tree by specific C++ classes.
    How to recognize nodes? Nodes of tree are classified according to certain syntactic category.
  - Associate attributes with parse tree nodes.
  - Perform computation by traversing the tree.
    Also, during building of the tree
- Advantage:
  - Modular design of compiler
  - Encapsulation of information
  - Extensibility of program
  - Re-usability

How to construct Parse Tree?

- Two components:
  1. Identify what parse tree nodes are
  2. Identify relationship between nodes.
- Identification and representation of parse tree nodes:
  1. Identification: simplest approach is to represent each syntactic category as a parse tree node.
     Although you may want to optimize this to combine intermediate nonterminals.
  2. Representation mechanism: Use C++ class to represent each node.
     Attributes associated with each node can be defined as a member of the class. (Note: inheritance can help us here.)
     Methods: represent certain dynamic behavior of the node. can be used to access certain information; perform any semantic analysis; Do some computation such as code generation.
- A parse tree is a set of parse tree nodes.
  Can be implemented using STL `vector` mechanism.

```
class ParseTreeNode {
   vector<ParseTreeNode *> children;
      :
}
```

- Result of this analysis will lead you to construct a set of parse tree nodes, disjoint at this juncture.

Example

Grammar:

```
Statement ::=   IfThenStatement      | IfThenElseStatement
              | ForStatement         | Block
              | EmptyStatement       | ExpressionStatement
              | ContinueStatement    | ReturnStatement
EmptyStatement ::=  ';'
ExpressionStatement ::=  StatementExpression ';'
StatementExpression ::=  Assignment
              | MethodInvocation
              | ClassInstanceCreationExpression
IfThenStatement ::=  if  '(' Expression ')' Statement
IfThenElseStatement ::=  if '(' Expression ')' Statement
                         else  Statement
ForStatement ::=   for '(' [ForInit] ';' [Expression] ';'
                           [ForUpdate]')' Statement
ForInit ::=    StatementExpressionList
            |  LocalVariableDeclaration
ForUpdate ::=  StatementExpressionList
StatementExpressionList ::=  StatementExpression
          (',' StatementExpression)*
ContinueStatement ::=  continue ';'
ReturnStatement ::=  return  [Expression]  ';'
```

Create a class for each nonterminal

```
class StatementClass ... { ... }
class EmptyStatementClass ... { ... }
class ExpressionStatement ... { ... }
class StatementExpression ... { ... }
class IfThenStatementClass ... { ... }
class ForStatementClass ... { ... }
class StatementExpressionListClass ... { ... }
class ContinueStatementClass ... { ... }
class ReturnStatementClasss ... { ... }
...
```

What should each class contain?

- For each NT, and its rule, look at its RHS and construct the class:
  `S ::= A c B d`
  Class for S will contain:

```
class SClass:  public ParseTreeNode {
   ParseTreeNode *getA();
   void setA(ParseTreeNode *A);
   ParseTreeNode *getc();
   void setc(ParseTreeNode *c);
   ParseTreeNode *getB();
   void setB(ParseTreeNode *B);
   ParseTreeNode *getd();
   void setd(ParseTreeNode *d);
      ⋮
}
```

  Note that ParseTreeNode contains a vector. So get and set methods can access the corresponding elements from vector
- Example for ForStatement:

```
class ForStatementClass:  public ParseTreeNode {
   ParseTreeNode *GetInitExpression() {
      return children[0];
   }
   ParseTreeNode *GetLoopCondition(); {
      return children[1];
   }
   ParseTreeNode *GetLoopUpdateExpression() {
      return children[2];
   }
   ParseTreeNode *GetBody(); {
      return children[3];
   }
   ⋮
};
```

How to construct Parse Tree? - cont'd.

- Step2: construct class-subclass relationships among parse tree node type.
- Hierarchy is an important aspect of context free grammar.

```
Statement ::=   IfThenStatement
              | IfThenElseStatement
              | ForStatement
              | Block
              | EmptyStatement
              | ExpressionStatement
              | ContinueStatement
              | ReturnStatement
```

  Captures information that `Statement` denotes general statements, whereas if-then-else, case, etc are more specific kind.
- Inheritance precisely captures this relationships:

```
class StatementClass: public ...
    { ... }
class IfThenClass: public StatementClass
     { ... }
class WhileStatementClass: public StatementClass
     { ... }
```

- class `StatementClass` will declare all common attributes and virtual methods

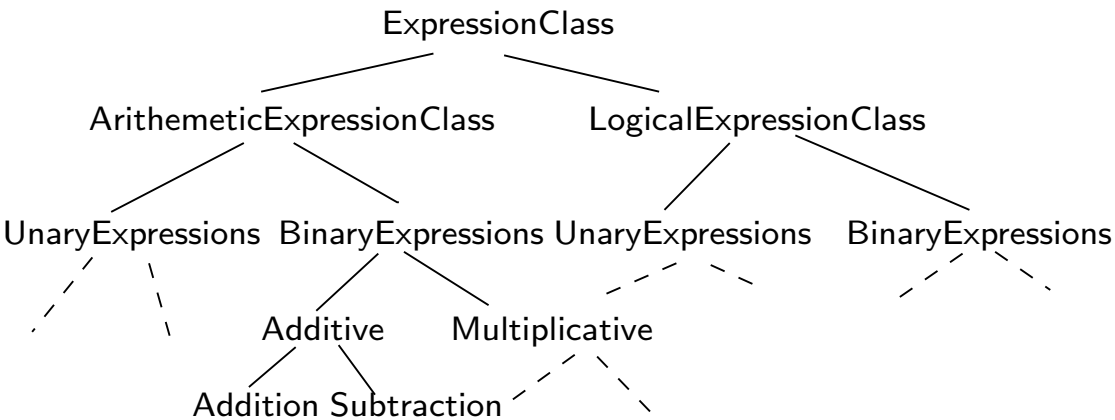
  `IfThenElseClass` will extend its behavior by adding things that are specific for if-then-else statements.
- Once you have designed the hierarchy, you can then now start to push information as well as computation up in the hierarchy.

Example

Grammar:

```
Expression ::=  Expression '*' Expression
        | Expression '/' Expression
        | Expression '+' Expression
        |  Expression '-' Expression
        | Expression '&&' Expression
        | Expression '||' Expression
        | Expression '==' Expression
        | Expression '!=' Expression
        | Expression '<' Expression
        | Expression '>' Expression
        | Expression '<=' Expression
        | Expression '>=' Expression
        | Assignment | '-' Expression
        | '+' Expression | '!' Expression
        | PrimitiveExpression
```

Hierarchy:



How can parse tree be constructed from yacc?

- After every rule, add an action that will create tree and add nodes.
- A blind approach to creating parse tree:

```
Statement ::=   IfThenStatement
              | IfThenElseStatement
              | ForStatement
              | Block
              | EmptyStatement
              | ExpressionStatement
              | ContinueStatement
              | ReturnStatement
      { $$ = $1}
EmptyStatement ::=  ';'
      { $$ = new EmptyStatementClass(); }
ExpressionStatement ::=  StatementExpression ';'
      { $$ = new ExpressionStementClass($1);}
StatementExpression ::=  Assignment
              | AutoExpression
              | MethodInvocation
              | ClassInstanceCreationExpression
      { $$ = $1;}
IfThenStatement ::=  if  '(' Expression ')' Statement
      { $$ = new IfThenStatementClass($3, $5); }
IfThenElseStatement ::=  if '(' Expression ')'
           Statement  else  Statement
      { $$ = new IfThenStatementClass($3, $5, $7); }
WhileStatement ::=  while '(' Expression ')' Statement
      { $$ = new WhileStatementClass($3, $5); }
```

- Can perform many optimizations in terms of creating parse tree node.