Abstract Syntax

Mooly Sagiv

html://www.cs.tau.ac.il/~msagiv/courses/wcc10.html

Outline

- The general idea
- CUP
- Motivating example
  Interpreter for arithmetic expressions
- The need for abstract syntax
- Abstract syntax for arithmetic expressions

Semantic Analysis during Recursive Descent Parsing

- Scanner returns "semantic values" for some tokens
- The function of every non-terminal returns the "corresponding subtree value"
- When $A \rightarrow B\ C\ D$ is applied
  the function for A can use the values returned by B, C, and D
  - The function can also pass parameters, e.g., to *D*(), reflecting left contexts

E → **num** E’

E’ → ε

E’→ **+ num** E’

```
int E() {
  switch (tok) {
   case num :   temp=tok.val; eat(num);
                return EP(temp);
   default: error(…); }}
int EP(int left) {
  switch (tok) {
  case $: return left;
  case + :   eat(+);
             temp=tok.val; eat(num);
             return EP(left + temp);
   default: error(…) ;}}
```

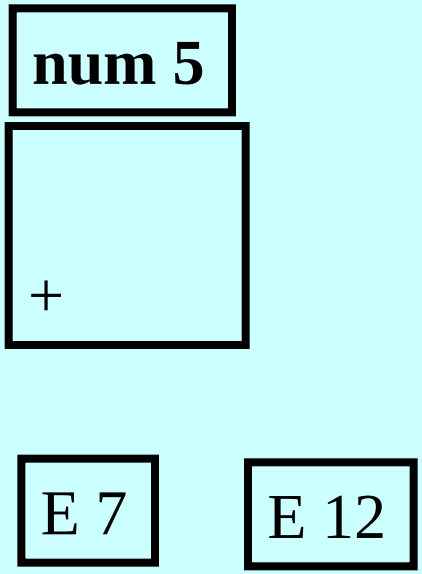
Semantic Analysis during Bottom-Up Parsing

- Scanner returns "semantic values" for some tokens
- Use parser stack to store the "corresponding subtree values"
- When $A \rightarrow B\ C\ D$ is reduced
  the function for A can use the values returned by B, C, and D
- No action in the middle of the rule

Example

E $\rightarrow$ E **+ num**

E $\rightarrow$ **num**



```
terminal Integer NUMBER;
terminal PLUS,MINUS,MULT,DIV;
terminal LPAREN, RPAREN;
terminal UMINUS;
non terminal Integer expr;
precedence left PLUS, MINUS;
precedence left DIV, MULT;
Precedence left UMINUS;
%%
expr ::= expr:e1 PLUS expr:e2
            {: RESULT = new Integer(e1.intValue() + e2.intValue()); :}
            | expr:e1 MINUS expr:e2
            {: RESULT = new Integer(e1.intValue() - e2.intValue()); :}
            | expr:e1 MULT expr:e2
            {: RESULT = new Integer(e1.intValue() * e2.intValue()); :}
            | expr:e1 DIV expr:e2
            {: RESULT = new Integer(e1.intValue() / e2.intValue()); :}
            | MINUS expr:e1 %prec UMINUS
            {: RESULT = new Integer(0 - e1.intValue(); :}
            | LPAREN expr:e1 RPAREN
            {: RESULT = e1; :}
            | NUMBER:n
            {: RESULT = n; :}
```

stack	input	action
$	7+11+17$	shift
num 7 $	+11+17$	reduce e → **num**
e 7 $	+11+17$	shift
+ e 7 $	11+17$	shift
num 11 + e 7 $	+17$	reduce e→ **num**

stack	input	action
e 11 + e 7 $	+17$	reduce e → e+e
e 18 $	+17$	shift
+ e 18 $	17$	shift
num 17 + e 18 $	$	reduce e→ num

stack	input	action
e 17 + e 18 $	$	reduce e::= e+e
e 35 $	$	accept

So why can’t we write all the compiler code in Bison/CUP?

Historical Perspective

- Originally parsers were written w/o tools
- yacc, bison, cup... make tools acceptable
- But it is still difficult to write compilers in parser actions (top-down and bottom-up)
  - Natural grammars are ambiguous
  - No modularity principle
  - Many useful programming language features prevent code generation while parsing
    - Use before declaration
    - gotos

Abstract Syntax

- Intermediate program representation
- Defines a tree - Preserves program hierarchy
- Generated by the parser
- Declared using an (ambiguous) context free grammar (relatively flat)
  - Not meant for parsing
- Keywords and punctuation symbols are not stored (Not relevant once the tree exists)
- Big programs can be also handled (possibly via virtual memory)

Issues

- Concrete vs. Abstract syntax tree
- Need to store concrete source position
- Abstract syntax can be defined by:
  - Ambiguous context free grammar
  - C recursive data type
  - “Constructor” functions
- Debugging routines linearize the tree

Abstract Syntax for Arithmetic Expressions

Exp → **id**	(IdExp)
Exp → **num**	(NumExp)
Exp → Exp Binop Exp	(BinOpExp)
Exp → Unop Exp	(UnOpExp)
Binop → **+**	(Plus)
Binop → **-**	(Minus)
Binop → *****	(Times)
Binop → **/**	(Div)
Unop → **-**	(UnMin)

```
package Absyn;
abstract public class Absyn { public int pos ;}
Exp extends Absyn {} ;
class IdExp extends Exp { String rep ;
        IdExp(r) { rep = r ;}
}
class NumExp extends Exp { int number ;
        NumExp(int n) { number = n ;}
}
class OpExp {
    public final static int PLUS=1;  public final static int Minus=2;
    public final static int  Times=3;  public final static int  Div=4;
}
final static int OpExp.PLUS, OpExp.Minus, OpExp.Times, OpExp.Div;
class BinExp extends Exp {
        Exp left, right;    OpExp op ;
        BinExp(Exp l, OpExp o, Bin Exp r) {
             left = l ;  op = o; right = r ;
            }
}
```

```
terminal Integer NUMBER;
terminal PLUS,MINUS,MULT,DIV;
terminal LPAREN, RPAREN;
terminal UMINUS;
nonterminal Exp expr;
precedence left PLUS, MINUS;
precedence left DIV, MULT;
Precedence left UMINUS;
%%
expr ::= expr:e1 PLUS expr:e2
            {: RESULT = new BinExp( e1, OpExp.PLUS, e2); :}
            | expr:e1 MINUS expr:e2
            {: RESULT = new BinExp(e1, OpExp.MINUS,  e2); :}
            | expr:e1 MULT expr:e2
            {: RESULT = new BinExp(e1, OpExp.PLUS, e2); :}
            | expr:e1 DIV expr:e2
            {: RESULT = new BinExp(e1, OpExp.DIV,  e2); :}
            | MINUS expr:e1 %prec UMINUS
            {: RESULT = new BinExp(new NumExp(0), OpExp.MINUS,  e1); :}
            | LPAREN expr:e1 RPAREN
            {: RESULT = e1; :}
            | NUMBER:n
            {: RESULT = new NumExp(n.intValue()); :}
```

Summary

- Jlex(Jflex) and CUP simplify the task of writing compiler/interpreter front-ends
- Abstract syntax provides a clear interface with other compiler phases
  - Supports general programming languages
- But the design of an abstract syntax for a given PL may take some time