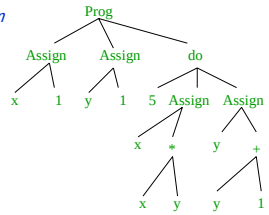
Code Generation & Software Testing

Lecture 4
CS 212 – Fall 2007

Recall

- We use *recursive descent parsing* to go from *program* to *AST* (Abstract Syntax Tree)

```
x = 1; y = 1;
do 5:
  x = x * y;
  y = y + 1;
  end;
end.
```



Prog(Assign(x,1),Assign(y,1),do(5,Assign(x,*(x,y)),Assign(y,+(y,1))))

Recall the Example Grammar

program → statement* **end** .

statement → name = expression ;

statement → **do** expression :
statement* **end** ;

expression → part [(**+** | **-** | ***** | **/**) part]

part → (name | number | **(** expression **)**)

name → (**x** | **y** | **z**)

- Notation:
  - * indicates zero or more occurrences
  - [ ] indicates zero or one occurrence
  - (| |) indicates choice

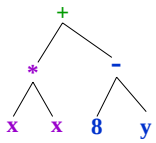
Recursion

- The grammar drives the design of the parser
  - We write a parsing method for each nonterminal
  - Within the method, each terminal token is checked; the nonterminals can take care of themselves (via recursive calls)
- The AST drives the design of the code generator
  - We write a code-generation method for each AST node-type
  - Within the method, we generate code for the node; the subtrees can take care of themselves (via recursive calls)

Code for Expressions

- Goal is to leave expression's value on top of the SaM stack
- For our example, there are 3 kinds of expression nodes:
  - Numbers (e.g., 42)
  - Variables (e.g., x)
    - We assume x is at mem 0, y at mem 1, and z at mem 2
  - Operators (e.g., +)
- Desired code
  - Number
    PUSHIMM 42
  - Variable
    PUSHOFF 0
    or
    PUSHOFF 1
    or
    PUSHOFF 2
  - Operator
    <code for left subtree>
    <code for right subtree>
    ADD

Example Expression Code




```
PUSHOFF 0
PUSHOFF 0
TIMES
PUSHIMM 8
PUSHOFF 1
SUB
ADD
```

Code For Assignment Statements

- Goal is to store the value of the <expression> into the <variable> (e.g., y)
  - We already have the code to place the expression's value on top of the stack
- Desired code

```
<code for expression>
STOREOFF 1
```

- Example: y = x + 5;

```
PUSHOFF 0
PUSHIMM 5
ADD
STOREOFF 1
```

Code For Do Statements

- This is harder because we have to maintain a counter
- Goal is to
  - Place do <expression> on top of stack to act as counter
  - If counter has reached zero we remove counter from stack and leave the loop
  - Generate code for all <statements> within the do-statement
  - Decrement the counter

```
<code for expression>
loop: DUP
NOT
JUMPC endloop
<code for statements>
PUSHIMM 1
SUB
JUMP loop
endloop: ADDSP -1
```

- Possible improvement: Code is wrong if <expression> is negative

Code for a Program

- Goal is to
  - Reserve space for the three variables (x, y, and z)
  - Print the values of the 3 variable at the end of the program
- Resulting code:

```
ADDSP 3
<code for statements>
WRITE
WRITE
WRITE
STOP
```

- Note that each type of AST node produces just a small amount of code
  - The do-statement was the most complicated
  - It produced 7 instructions of its own

Example Program and Resulting Code

```
x = 1; y = 1;
do 5:
  x = x * y;
  y = y + 1;
  end;
end.
```

```
ADDSP 3
PUSHIMM 1
STOREOFF 0
PUSHIMM 1
STOREOFF 1
PUSHIMM 5
do0: DUP
NOT
JUMPC end1
PUSHOFF 0
PUSHOFF 1
TIMES
STOREOFF 0
PUSHOFF 1
PUSHIMM 1
ADD
STOREOFF 1
PUSHIMM 1
SUB
JUMP do0
end1: ADDSP –1
WRITE
WRITE
WRITE
STOP
```

EBNF

- BNF = Backus-Naur Form
  - A way of representing a grammar for a programming language
  - Originally Backus *Normal* Form
    - Switched at suggestion of Knuth (partly because not really a *normal* form)
    - Naur was editor of Algol-60 document which used BNF
- EBNF = Extended BNF
  - Basically, BNF with some extra simplifying notation
  - There is an official standard, but common to modify it
- Typical constructs
  - Way to distinguish between terminals and nonterminals
  - * for repetition
  - [ ] for optional
  - (| |) for choice

Example Grammar Notation: Java

Statement:
Block
if *ParExpression Statement* [else *Statement*]
for (*ForInit*$_{Opt}$; *[Expression]* ; *ForUpdate*$_{Opt}$) *Statement*
while *ParExpression Statement*
do *Statement* while *ParExpression* ;
try *Block (Catches* | *[Catches]* finally *Block)*
switch *ParExpression* { *SwitchBlockStatementGroups* }
synchronized *ParExpression Block*
return *[Expression]* ;
throw *Expression* ;
break *[Identifier]*
continue *[Identifier]*
;
ExpressionStatement
Identifier : *Statement*

Example Grammar Notation: Python

```
if_stmt ::=
        "if" expression ":" suite
          ( "elif" expression ":" suite )*
          ["else" ":" suite]

while_stmt ::=
        "while" expression ":" suite
          ["else" ":" suite]

for_stmt ::=
        "for" target_list "in" expression_list
         ":" suite
          ["else" ":" suite]
```

Grammar for Bali (Version for Part 2)

```
program -> int main ( ) :
        [ declarations ] :
        statement* end
declarations ->
        type name ( , type name )*
type -> ( int | boolean )
statement -> reference = expression ;
statement -> if expression
        then statement*
        [ else statement*] endif
statement -> loop statement*
        ( while | until ) expression ;
        statement* endloop
statement -> return expression ;
statement -> print expression
        ( , expression )* ;
```

- Nonterminals are shown as plain
- Terminals are shown as **bold** with keywords shown as **bold-blue**
- Nonspecific terminals are shown as ***bold italic***
- An arrow -> indicates a production rule.
- Parentheses ( ) are used for grouping.
- Asterisk * indicates repetition (0 or more times).
- Brackets [ ] indicate an optional occurrence.
- A vertical bar | indicates choice.

Rest of the Grammar for Bali (Part 2)

```
reference -> name
expression -> [ + | - | not ] term ( binaryOp term )*
binaryOp -> arithmeticOp | comparisonOp | booleanOp
arithmeticOp -> + | - | * | / | %
comparisonOp -> < | <= | == | != | > | >=
booleanOp -> and | or
term -> literal | ( expression ) | inputValue | reference
literal -> integer | true | false
inputValue -> readInt
```

Coding Quality

- Pareto Principle
  - Named for Vilfredo Pareto, Italian economist, late 1800's
  - An 80/20 rule that shows up often
    - 80% of complaints are about 20% of the products
    - 80% of the decisions are completed during 20% of a meeting
- Software version: 80% of software defects occur in just 20% of the modules
- NSA study [Drake, IEEE Computer, 1996] on 25 million lines of code
  - 70-80% of problems were due to 10-15% of modules
  - 90% of all defects were in modules containing 13% of the code
  - 95% of *serious* defects were from just 2.5% of the code
- Sturgeon's Revelation?

Unit vs. Integration Testing

- Unit testing
  - Testing of a single module
  - If a unit fails to match its specification then it is considered to be incorrect
- Integration testing
  - Testing of the entire program
  - Failure here may imply that the specifications are incorrect
  - Integration testing is usually harder than unit testing

Tools for Testing

- Goal: automate as much of the testing as we can
  - Some parts can't be automated
    - Process of developing test cases is difficult and usually cannot be fully automated
  - But we can automate the testing process itself
    - Both DrJava and Eclipse include facilities for using JUnit (http://www.junit.org)
      - Simplifies the process of writing unit tests
  - Can make use of *drivers* and *stubs*
- A driver
  - Calls the unit being tested and keeps track of how it performs
- A stub
  - Simulates a program-part that is called by the unit being tested
- Both can interact with a file or with a person
  - Example: a driver can read calling parameters from a file and save test results to another file