"Debugging is twice as hard as writing the code in the first place. Therefore, if you write the code as cleverly as possible, you are, by definition, not smart enough to debug it."

- Brian W. Kernighan

CSE341
Programming Languages

Lecture 5 – October 27, 2015

Expressions

Chapter 6 slides are adapted from R.W. Sebesta, C. Li & W. He and V. Shmatikov

Control

- Control:

  what gets executed, when, and in what order

- Abstraction of control:
  - Expression
  - Statement
  - Exception handling
  - Procedures and functions

Expression vs. Statement

- In pure (mathematical) form:
  - Expression:
    - no side effect
    - return a value
  - Statement:
    - side effect
    - no return value
- Functional languages aim at achieving this pure form
- No clear-cut in most languages

Expression

- Constructed recursively:
  - Basic expression (literal, identifiers)
  - Operators, functions, special symbols
- Number of operands:
  - unary, binary, ternary operators
- Operator, function: equivalent concepts

```
(3+4)*5
```
(infix notation)

```
mul(add(3,4), 5)
```

```
"*"("+"(3,4),5)
```
(Ada, prefix notation)

```
(* (+ 3 4) 5)
```
(LISP, prefix notation)

Postfix notation

- PostScript:

```
%!PS
/Courier findfont
20 scalefont
setfont
72 500 moveto
(Hello world!) show
showpage
```

http://en.wikipedia.org/wiki/PostScript

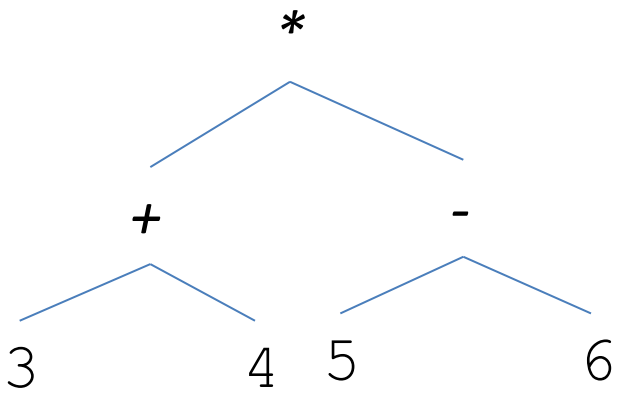
Expression and Side Effects

- Side Effects:
  - Changes to memory, input/output
  - Side effects can be undesirable
  - But a program without side effects does nothing!
- Expression:
  - No side effect: Order of evaluating sub-expressions does not matter (mathematical forms)
  - Side effect: Order matters

Applicative Order Evaluation (Strict Evaluation)

- Evaluate the operands first, then apply operators (bottom-up evaluation)

  (sub-expressions evaluated, no matter whether they are needed)



- But is 3+4 or 5-6 evaluated first?

Order Matters

C:

```
int x=1;
int f(void) {
   x=x+1;
   return x;
}
main(){
   printf("%d\n", x + f());
   return 0;
}
```

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Java:

```
class example {
  static int x = 1;
  public static int f() {
     x = x+1;
     return x;
  }
  public static void main(String[] args){
    System.out.println(x+f());
  }
}
```

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Many languages don't specify the order, including C, java.

- C: usually right-to-left
- Java: always left-to-right, but not suggested to rely on that.

Expected Side Effect

- Assignment (expression, not statement)

```
x = (y = z)
```

(right-associative operator)

Why?

x++, ++x

```
int x=1;
int f(void) {
   return x++;
}
main(){
   printf("%d\n", x + f());
   return 0;
}
```

Sequence Operator

- (expr1, expr2, …, expr*n*)
  - Left to right (this is indeed specified in C)
  - The return value is expr*n*

```
x=1;
y=2;
x = (x=x+1, y++, x+y);
printf("%d\n",x);
```

Non-strict Evaluation

- Evaluating an expression without necessarily evaluating all the sub-expressions

- short-circuit Boolean expression
- if-expression, case-expression

Short-Circuit Evaluation

- `if (false and x) … if (true or x)…`
  - No need to evaluate x, no matter x is true or false
- What is it good for?
  - `if (i <=lastindex and a[i]>=x)…`
  - `if (p != NULL and p->next==q)…`
- Ada: allow both short-circuit and non short-circuit.
  - `if (x /= 0) and then (y/x > 2) then ...`
  - `if (x /= 0) and (y/x > 2) then ...` ?
  - `if (ptr = null) or else (ptr.x = 0) then ...`
  - `if (ptr = null) or (ptr.x = 0) then ...` ?

if-expression

- `if (test-exp, then-exp, else-exp)`

  ternary operator
  - test-exp is always evaluated first
  - Either then-exp or else-exp are evaluated, not both

  - `if e1 then e2 else e3` (ML)
  - `e1 ? e2 : e3` (C)

- Different from if-statement?

case-expression

- ML:

```
case color of
        red => “R’’ |
        blue => “B’’ |
        green => “G” |
        _  =>  “AnyColor”;
```

Normal order evaluation (lazy evaluation)

- When there is no side-effect:

  Normal order evaluation (expressions evaluated in mathematical form)
  - Operation evaluated ***before*** the operands are evaluated;
  - Operands ***evaluated only when necessary***.

```
int double (int x) { return x+x; }
int square (int x) { return x*x; }
```

Applicative order evaluation : square(double(2)) = …

Normal order evaluation : square(double(2)) = …

Example

- int double (int x) { return x+x; }
- int square (int x) { return x*x; }
- Normal order evaluation: square(double(2)) =
  - square(double(2))
  - double(2)*double(2)
  - (2+2)*(2+2) → (with left to right order) 4*(2+2) → 4*4 →16
- Applicative order evaluation: square(double(2)) =
  - square(double(2))
  - square(2+2)
  - square(4)
  - 4*4 → 16

What is it good for?

```
(p!=NULL) ? p->next : NULL
```

```
int if_exp(bool x, int y, int z) {
  if (x)
     return y;
  else
     return z;
}
if_exp(p!=NULL, p->next, NULL);
```

With side effect, it may hurt you:

```
int get_int(void) {
  int x;
  scanf("%d" &x);
  return x;
}
```

Examples

- Call by Name (Algol60)
- Macro

```
#define swap(a, b) {int t; t = a; a = b; b = t;}
```

  - What are the problems here?

Unhygienic Macros

- Call by Name (Algol60)
- Macro

```
#define swap(a, b) {int t; t = a; a = b; b = t;}

main (){
  int t=2;
  int s=5;
  swap(s,t);
}
```

```
main (){
  int t=2;
  int s=5;
  {int t; t = s; s = t; t = t;}
}
```

```
#define DOUBLE(x) {x+x;}

main() {
  int a;
  a = DOUBLE(get_int());
  printf("a=%d\n", a);
}
```

```
main() {
  int a;
  a = get_int()+get_int();
  printf("a=%d\n", a);
}
```

Assignments

- Central construct in imperative languages
  - Functional?
- General syntax:

  `<target_var> <assign_operator> <expression>`
- Operator:

  "=", ":="
- Watch it when overloaded

Assignment: Conditional Targets

- Conditional targets (as in Perl)

```
($flag ? $count1 : $count2) = 0;
```

equivalent to:

```
if ($flag) {
   $count1 = 0;
} else {
   $count2 = 0;
}
```

- Declaration order?
- Binding?

Assignment: Compound Operators

- A shorthand method for specifying commonly needed form of assignment

  examples:

  ```
  a = a + b
  ```

  can be written as:

  ```
  a += b
  ```

- Algol, C/C++, JavaScript, Perl, Python, Ruby.

Unary Assignment

- Unary assignment operators in C-based languages combine increment and decrement with assignment
- Examples:

```
sum = ++count;  // count inc. added to sum
sum = count++;  // count inc. added to sum
```

Assignment as Expressions

- In C-based languages, Perl and JavaScript, assignment statements produce results and can be used as operands
- Examples:

```
while ((ch = getchar()) != EOF) { … }
```

Multiple/List Assignments

- Perl and Ruby support list assignments
- Example:

```
($first, $second, $third) = (20, 30, 40);
($first, $second) = ($second, $third);
```

Statements

- If-statements, case-(switch-)statements, loops