CSC 347 - Concepts of Programming Languages

Statements and Expressions

Instructor: James Riely

Learning Objectives

❓ What should be the basic building blocks of computations?

- Identify different ways of expressing computations
- Identify the difference between statement sequences and compound expressions

Does it Translate?

Scala

```
1 def f (x: Int) : Int =
2   val y: Int = if x!=0 then 1 else 2
3   y
4 end f
```

- Conditionally set a variable

Is this Java/C?

```
1 int f (int x) {
2   int y = if (x!=0) 1 else 2;
3   return y;
4 }
```

⚠ In Java/C, `if ... else` is statement language, not expression language

Does it Translate?

Java/C

```java
int f (int x) {
  int y = x!=0 ? 1 : 2;
  return y;
}
```

- Conditionally set a variable

Is this Scala?

```scala
def f (x: Int) : Int =
  var y: Int = (x!=0 ? 1 : 2)
  y
end f
```

⚠ Ternary operator not in Scala expression language

💡 `if ...` in Scala expression language!

Does it Translate?

Scala

```scala
def f (x: Int) : Int =
  val y: Int = {
    var i = x
    var z=0
    while i>0 do {i=i-1; z=z+1}
    z
  }
  y
end f
```

- Set value of `y` with a compound expression

Is this Java/C?

```java
int f (int x) {
  int y = {
    int i=x;
    int z=0;
    while (i>0) {i--; z++;}
    return z;
  }
  return y;
}
```

- ⚠ Loops and `;` are not in the Java/C expression language
- How can we make it Java/C?

Does it Translate?

Scala

```scala
def g (x: Int) : Int =
  var i = x
  var z = 0
  while i>0 do { i=i-1; z=z+1 }
  z
end g

def f (x: Int) : Int =
  val y = g(x)
  y
end f
```

Java/C

```java
int g (int x) {
  int i=x;
  int z=0;
  while (i>0) { i--; z++; }
  return z;
}

int f (int x) {
  int y = g(x);
  return y;
}
```

- Functions are in the expression language of Scala, Java, and C

Statements and Expressions

- Assembly language consists of *statements*

```
1 mov eax, 5
2 add eax, 6
3 mov ebx, eax
```

- *Expressions* are a more abstract way of expressing computations

```
1 5+6
```

- Many imperative PL distinguish statement language from expression language
- Functional languages tend to emphasize expressions (Scala has only expressions)

Pure vs Side-Effecting Expressions

- A mathematical function takes arguments and gives results
- An expression is *pure* if that is all it does
- Anything else is a *side effect*
  - Assignment to a variable
  - Change of control (goto)
  - I/O (console, network)
  - etc.

- Pure expression does not modify store ξ

$$\frac{\langle \mathtt{e}_1,\xi_0\rangle \Downarrow \langle v_1,\xi_1\rangle \quad \langle \mathtt{e}_2,\xi_1\rangle \Downarrow \langle v_2,\xi_2\rangle}{\langle \mathtt{e}_1 \mathtt{+} \mathtt{e}_2,\xi_0\rangle \Downarrow \langle v_1 + v_2,\xi_2\rangle}\ (\text{Add})$$

- Side-effecting expression modifies store ξ

$$\frac{\langle \mathtt{e},\xi_0\rangle \Downarrow \langle v,\xi_1\rangle}{\langle \mathtt{x} \mathtt{:=} \mathtt{e},\xi_0\rangle \Downarrow \langle v,\xi_1\{\mathtt{x} \mapsto v\}\rangle}\ (:=)$$

Expressions

- Literals (boolean, character, integer, string)
- Operators (arithmetic, bitwise, logical)
- Function calls

```
1 f(1 + 2 * "hello".length)
```

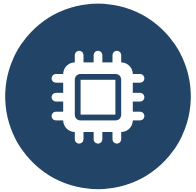
- Assignment

```
1 var y = 0
2 val x = y = 5
```

```
1 int y = 0;
2 int x = y = 5;
```

❓ Type and value of `x`?

💡 In Scala, everything is an expression!



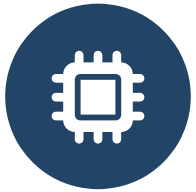
Statements in C

- Expression statements (including assignment)

```
1 printf("hello");
2 ^^^^^^^^^^^^^^^    expression
3 ^^^^^^^^^^^^^^^^   statement
```

- Return statements

```
1 return 1+x;
2        ^^^    expression
3 ^^^^^^^^^^^   statement
```



Statements in C

- Selection statements (if-then-else; switch-case)
- Iteration statements (while; do-while; for)

```c
int count = 0;
while (1) {
  int ch = getchar();
  switch (ch) {
    case -1: return count;
    case 'a': count = count + 1;
    default: continue;
  }
}
```

⚠ Cannot use statements verbatim as part of expressions

💡 Use functions to turn statements into expressions

Side-Effecting Expressions in C

```
1 int x = 1;
2 printf ("%d\n", ++x);   // pre increment, prints 2
3 // value of x is now 2
```

```
1 int x = 1;
2 printf ("%d\n", x++);   //
3 //
```

```
1 x = 1 + (y = 5);        //
```

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

Side-Effecting Expressions in C

```c
int x = 1;
printf ("%d\n", ++x);   // pre increment, prints 2
// value of x is now 2
```

```c
int x = 1;
printf ("%d\n", x++);   // post increment, prints 1
// value of x is now 2
```

```c
x = 1 + (y = 5);        //
```

```c
int x = 1;
printf ("%d\n", (x = x + 1) + x); //
```

Side-Effecting Expressions in C

```
1 int x = 1;
2 printf ("%d\n", ++x);   // pre increment, prints 2
3 // value of x is now 2
```

```
1 int x = 1;
2 printf ("%d\n", x++);   // post increment, prints 1
3 // value of x is now 2
```

```
1 x = 1 + (y = 5);        // assigns 5 to y and 6 to x
```

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

Side-Effecting Expressions in C

```c
int x = 1;
printf ("%d\n", ++x);   // pre increment, prints 2
// value of x is now 2
```

```c
int x = 1;
printf ("%d\n", x++);   // post increment, prints 1
// value of x is now 2
```

```c
x = 1 + (y = 5);        // assigns 5 to y and 6 to x
```

```c
int x = 1;
printf ("%d\n", (x = x + 1) + x); // no "sequence point", undefined!
```

💡 *Sequence point:* A point in the execution of a C program at which all previous side effects are guaranteed to be complete.

Side-Effects in OOP

- Side effects are common in object-oriented programming

```
1 class C {
2   private int x = 0;
3   private int y = 0;
4   public int f(int z) {
5     x = x-z;
6     return x;
7   }
8   public int g() {
9     y = y+5;
10    return y;
11  }
12 }
13 C c = new C();
14 c.f(c.g()); // same as x -= (y += 5)
```

- Results often depend on object state → potentially on entire execution history

Sequencing in C Expressions

- Operator `,` creates a sequence of expressions: last expression provides value

Statement sequence

```c
int main () {
  int x = 5;
  x *= 2;
  printf ("%d\n", x);
}
```

Expression sequence

```c
int main () {
  int x = 5;
  printf ("%d\n", (x *= 2, x));
}
```

Summary

Statements

- Change memory
- Are executed in sequence

Expressions

- Pure vs. side-effecting
- Sequencing by operator in expression language, e.g., C `e1, e2, ... en`
- Conditional by operator in expression language, e.g., C `e1 ? e2 : e3`