

CSC 347 - Concepts of Programming Languages

Statements and Expressions

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Learning Objectives

- ❓ What should be the basic building blocks of computations?
 - Understand different ways of expressing computations
 - Understand the importance of sequencing in computations



PL Development

- Assignment: `x := 5`, comparison `x >= y`, conditional `if (x<4) then 2 else 3`
- Develop syntax for picking a random value from an interval
- `x := * from [0,10]`
- Develop syntax for picking a value that satisfies some property
- `x := * s.t. 0 <= x`
- Express ordinary assignment in terms of the property-satisfying assignment above
- `x := 5` is shortcut for `x := * s.t. x=5`
- What else do popular programming languages provide?



Is this Accepted Syntax?

Is this Scala?

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

- Enter in REPL to find out

Is this C?

```
1 int f (int x) {  
2   int y;  
3   if (x) y=1; else y=2;  
4   return y;  
5 }
```

- Compile to find out



Is this Accepted Syntax?

Is this Scala?

```
1 def f (x: Int) : Int = {  
2   var y: Int = 0  
3   y = if x!=0 then 1 else 2  
4   y  
5 }
```

Is this C?

```
1 int f (int x) {  
2   int y;  
3   y = if (x) 1 else 2;  
4   return y;  
5 }
```

⚠ Not accepted in C, `if ... else` is statement language, not expression language



Is this Accepted Syntax?

Is this Scala?

```
1 def f (x: Int) : Int = {  
2   var y: Int = 0  
3   y = (x!=0 ? 1 : 2)  
4   y  
5 }
```

⚠ Ternary operator not in Scala expression language

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

Is this C?

```
1 int f (int x) {  
2   int y;  
3   y = x ? 1 : 2;  
4   return y;  
5 }
```



Is this Accepted Syntax?

Is this Scala?

```
1 def f (x: Int) : Int = {  
2   var xx = x  
3   var y: Int = 0  
4   y = { var z=0  
5         while (xx>0) do {xx=xx-1; z=z+1}  
6         z }  
7   y  
8 }
```

Is this C?

```
1 int f (int x) {  
2   int y;  
3   y = { int z=0;  
4         while (x>0) {x--; z++;}  
5         return z; }  
6   return y;  
7 }
```

- ⚠ Loops and variable declarations are not in the C expression language
- How can we make it C?



Is this Accepted Syntax?

Is this Scala?

```
1 def g (x: Int) : Int = {  
2   var xx = x  
3   var z = 0  
4   while xx>0 do { xx=xx-1; z=z+1 }  
5   z  
6 }  
7 def f (x: Int) : Int = g(x)
```

Is this C?

```
1 int g (int x) {  
2   int z=0;  
3   while (x>0) { x--; z++; }  
4   return z;  
5 }  
6 int f (int x) {  
7   return g(x);  
8 }
```

- Functions are in the expression language of Scala 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.

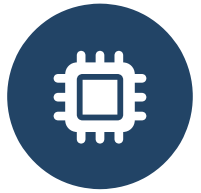


Expressions

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

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

💡 Scala does not have statements, everything is an expression!



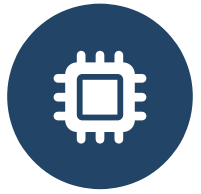
Statements in C

- 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)

```
1 int count = 0;
2 while (1) {
3     int ch = getchar();
4     switch (ch) {
5         case -1: return count;
6         case 'a': count = count + 1;
7         default: continue;
8     }
9 }
```

- ⚠ Cannot use statements verbatim as part of expressions
- ❓ How can we turn statements into an expression?



Side-Effecting Expressions in C

- Post-increment

```
1 x++
```

- Add and assign

```
1 x += 2
```

- Assignment

```
1 x = (y = 5)
```

- Combined

```
1 x -= (y += 5)
```



Side-Effecting Expressions in C

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

```
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

```
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

```
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);    //
```

```
1 int x = 1;
2 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

```
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);    // no "sequence point", undefined!
```



Sequencing in Expressions

- Scala { e1; e2; ...; en }

```
1 {  
2   e1  
3   e2  
4   ...  
5   en  
6 }
```

- C (e1, e2, ..., en)

```
1 (  
2   e1,  
3   e2,  
4   ...  
5   en  
6 )
```

- e1 ... en-1 executed for side effect
- Result is the value of en
- A C example:

```
1 string s;  
2 while(read_string(s), s.len() > 5) {  
3   // do something  
4 }
```



Sequencing in C Expressions

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

```
1 int main () {  
2     int x = 5;  
3     printf ("%d\n", (x *= 2, x));  
4     // behavior defined because comma operator introduces sequence point  
5 }
```



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`

- ❓ Should variable declarations be statements or expressions? What are they in C?
- ❓ Should loops be statements or expressions? What are they in C?