

6.4 — Increment/decrement operators, and side effects

ALEX SEPTEMBER 11, 2023

Incrementing and decrementing variables

Incrementing (adding 1 to) and decrementing (subtracting 1 from) a variable are both so common that they have their own operators.

Operator	Symbol	Form	Operation
Prefix increment (pre-increment)	++	++x	Increment x, then return x
Prefix decrement (pre-decrement)	--	--x	Decrement x, then return x
Postfix increment (post-increment)	++	x++	Copy x, then increment x, then return the copy
Postfix decrement (post-decrement)	--	x--	Copy x, then decrement x, then return the copy

Note that there are two versions of each operator -- a prefix version (where the operator comes before the operand) and a postfix version (where the operator comes after the operand).

Prefix increment and decrement

The prefix increment/decrement operators are very straightforward. First, the operand is incremented or decremented, and then expression evaluates to the value of the operand. For example:

```
#include <iostream>

int main()
{
    int x { 5 };
    int y { ++x }; // x is incremented to 6, x is evaluated to the value 6, and 6 is assigned to y

    std::cout << x << ' ' << y << '\n';
    return 0;
}
```

This prints:

```
6 6
```

Postfix increment and decrement



The postfix increment/decrement operators are trickier. First, a copy of the operand is made. Then the operand (not the copy) is incremented or decremented. Finally, the copy (not the original) is evaluated. For example:

```
#include <iostream>

int main()
{
    int x { 5 };
    int y { x++ }; // x is incremented to 6, copy of original x is evaluated to the value 5, and 5 is assigned to y

    std::cout << x << ' ' << y << '\n';
    return 0;
}
```

This prints:

```
6 5
```

Let's examine how this line 6 works in more detail. First, a temporary copy of x is made that starts with the same value as x (5). Then the actual x is incremented from 5 to 6. Then the copy of x (which still has value 5) is returned and assigned to y. Then the temporary copy is discarded.

Consequently, y ends up with the value of 5 (the pre-incremented value), and x ends up with the value 6 (the post-incremented value).

Note that the postfix version takes a lot more steps, and thus may not be as performant as the prefix version.



More examples

Here is another example showing the difference between the prefix and postfix versions:

```
#include <iostream>

int main()
{
    int x { 5 };
    int y { 5 };
    std::cout << x << ' ' << y << '\n';
    std::cout << ++x << ' ' << --y << '\n'; // prefix
    std::cout << x << ' ' << y << '\n';
    std::cout << x++ << ' ' << y-- << '\n'; // postfix
    std::cout << x << ' ' << y << '\n';

    return 0;
}
```

This produces the output:

```
5 5
6 4
6 4
6 4
7 3
```

On the 8th line, we do a prefix increment and decrement. On this line, x and y are incremented/decremented before their values are sent to std::cout, so we see their updated values reflected by std::cout.

On the 10th line, we do a postfix increment and decrement. On this line, the copy of x and y (with the pre-incremented and pre-decremented values) are what is sent to `std::cout`, so we don't see the increment and decrement reflected here. Those changes don't show up until the next line, when x and y are evaluated again.

When to use prefix vs postfix



In many cases, the prefix and postfix operators produce the same behavior:

```
int main()
{
    int x { 0 };
    ++x; // increments x to 1
    x++; // increments x to 2

    return 0;
}
```

In cases where code can be written to use either prefix or postfix, prefer the prefix versions, as they are generally more performant, and less likely to cause surprises.

Best practice
Favor the prefix versions, as they are more performant and less likely to cause surprises.

Use the postfix versions when doing so produces significantly more concise or understandable code than the equivalent code written using the prefix versions.

Side effects

A function or expression is said to have a **side effect** if it has some observable effect beyond producing a return value.

Common examples of side effects include changing the value of objects, doing input or output, or updating a graphical user interface (e.g. enabling or disabling a button).



Most of the time, side effects are useful:

```
x = 5; // the assignment operator has side effect of changing value of x
++x; // operator++ has side effect of incrementing x
std::cout << x; // operator<< has side effect of modifying the state of the console
```

The assignment operator in the above example has the side effect of changing the value of x permanently. Even after the statement has

finished executing, x will still have the value 5. Similarly with operator++, the value of x is altered even after the statement has finished evaluating. The outputting of x also has the side effect of modifying the state of the console, as you can now see the value of x printed to the console.

Side effects can cause order of evaluation issues

In some cases, side effects can lead to order of evaluation problems. For example:

```
#include <iostream>

int add(int x, int y)
{
    return x + y;
}

int main()
{
    int x { 5 };
    int value{ add(x, ++x) }; // undefined behavior: is this 5 + 6, or 6 + 6?
    // It depends on what order your compiler evaluates the function arguments in

    std::cout << value << '\n'; // value could be 11 or 12, depending on how the above line evaluates!

    return 0;
}
```

The C++ standard does not define the order in which function arguments are evaluated. If the left argument is evaluated first, this becomes a call to add(5, 6), which equals 11. If the right argument is evaluated first, this becomes a call to add(6, 6), which equals 12! Note that this is only a problem because one of the arguments to function add() has a side effect.



As an aside...

The C++ standard intentionally does not define these things so that compilers can do whatever is most natural (and thus most performant) for a given architecture.

The sequencing of side effects

In many cases, C++ also does not specify when the side effects of operators must be applied. This can lead to undefined behavior in cases where an object with a side effect applied is used more than once in the same statement.

For example, the expression `x + ++x` is unspecified behavior. When `x` is initialized to `1`, Visual Studio and GCC evaluate this as `2 + 2`, and Clang evaluates it as `1 + 2`! This is due to differences in when the compilers apply the side effect of incrementing `x`.

Even when the C++ standard does make it clear how things should be evaluated, historically this has been an area where there have been many compiler bugs. These problems can generally all be avoided by ensuring that any variable that has a side-effect applied is used no more than once in a given statement.

Warning

C++ does not define the order of evaluation for function arguments or the operands of operators.

Warning

Don't use a variable that has a side effect applied to it more than once in a given statement. If you do, the result may be undefined.

One exception is for simple assignment expression statements like `x = x + y;` (which could also be rewritten as `x += y`).



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