

Modern C++ Programming

3. BASIC CONCEPTS II

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Enumerators

Enumerated Types

Enumerator

An **enumerator** ([enum](#)) is a data type that groups a set of named integral constants

```
enum color_t { BLACK, BLUE, GREEN = 2 };
```

```
color_t color = BLUE;
```

```
cout << (color == BLACK); // print false
```

The problem:

```
enum color_t { BLACK, BLUE, GREEN };
```

```
enum fruit_t { APPLE, CHERRY };
```

```
color_t color = BLACK;    // int: 0
```

```
fruit_t fruit = APPLE;    // int: 0
```

```
cout << (color == fruit); // print 'true'!!
```

```
// and, most importantly, does the match between a color and
```

```
// a fruit make any sense?
```

Enumerated Types (Strongly Typed)

```
enum class
```

C++11 introduces a *type safe* enumerator `enum class` (scoped enum) data type that are not implicitly convertible to `int`

```
enum class Color { BLACK, BLUE, GREEN = 2 };
```

```
enum class Fruit { APPLE, CHERRY };
```

```
Color color = Color::BLUE;
```

```
Fruit fruit = Fruit::APPLE;
```

```
// cout << (color == fruit); // compile error
```

```
//     we are trying to match colors with fruits
```

```
//     BUT, they are different things entirely
```

```
// int a = Color::GREEN; // compile error
```

- `enum class` can be compared

```
enum class Color { RED = 1, GREEN = 2, BLUE = 3 };  
  
cout << (Color::RED < Color::GREEN); // print true
```

- `enum class` does not support other operations

```
enum        color_t { RED = 1, GREEN = 2, BLUE = 3 };  
enum class Color  { RED = 1, GREEN = 2, BLUE = 3 };  
  
int v = RED + GREEN; // ok  
// int v = Color::RED + Color::GREEN; // compile error
```

- The size of `enum class` can be set

```
#include <cstdint>  
enum class Color : int8_t { RED = 1, GREEN = 2, BLUE = 3 };
```

- `enum class` can be explicitly converted

```
int a = (int) Color::GREEN; // ok
```

- `enum class` should be always initialized

```
enum class Color { RED = 1, GREEN = 2, BLUE = 3 };
```

```
Color my_color; // "my_color" may be 0!!
```

- `enum class` can contain alias

```
enum class Device { PC = 0, COMPUTER = 0, PRINTER = 1 };
```

- `enum class` is automatically enumerated

```
enum class Color { RED, GREEN = -1, BLUE, BLACK };
```

```
//           (0) (-1)           (0) (1)
```

```
Color::RED == Color::BLUE; // true
```

- C++17 Cast from *out-of-range values* to `enum class` leads to undefined behavior

```
enum Color { RED = 0, GREEN = 1, BLUE = 2 };

int main() {
    Color value = (int) 3; // undefined behavior
}
```

- C++17 `enum class` supports *direct-list-initialization*

```
enum class Color { RED = 0, GREEN = 1, BLUE = 2 };

Color a{2};           // ok, equal to Color:BLUE
// Color b{4};       // compile error
// Color c = {2};    // compile error
Color d = Color{2};  // ok, equal to Color:BLUE
```


C++20 allows introducing the enumerator identifiers into the local scope

```
enum class Color { RED, GREEN, BLUE };  
  
switch (x) {  
    using enum Color; // C++20  
    case RED:  
    case GREEN:  
    case BLUE:  
}
```

struct, union, and **Bitfield**

struct

A structure `struct` allows aggregating different variables into a single unit

```
struct A {  
    int    x;  
    char  y;  
    float z;  
};
```

C++20 introduces *designated initializer list*

```
A a1{1, 0, 2};           // a.x == 1, a.y == 0, a.z == 2  
A a2{.x = 1, .z = 2}; // designated initializer list  
  
void f(A a) {}  
f({.x = 1, .z = 2})    // designated initializer list
```

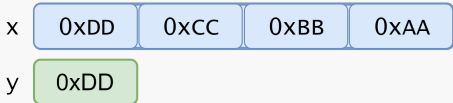
Union

A **union** is a special data type that allows to store different data types in the same memory location

- The **union** is only as big as necessary to hold its *largest* data member
- The **union** is a kind of “*overlapping*” storage

```
union A {  
    int x;  
    char y;  
};
```

```
A a;  
A.x = 0xAABBCCDD
```



Note: little endian

```
union A {
    int x;
    char y;
}; // sizeof(A): 4

A a;
a.x = 1023; // bits: 00..0000011111111111
a.y = 0;    // bits: 00..0000011000000000
cout << a.x; // print 512 + 256 = 768
```

NOTE: Little-Endian encoding maps the bytes of a value in memory in the reverse order. `y` maps to the last byte of `x`

C++17 introduces `std::variant` to represent a type-safe union

Bitfield

A **bitfield** is a variable of a structure with a predefined bit width.
A bitfield can hold bits instead bytes

```
struct S1 {
    int b1 : 10; // range [0, 1023]
    int b2 : 10; // range [0, 1023]
    int b3 : 8;  // range [0, 255]
}; // sizeof(S1): 4 bytes

struct S2 {
    int b1 : 10;
    int    : 0; // reset: force the next field
             // to start at bit 32
    int b2 : 10;
}; // sizeof(S1): 8 bytes
```

using, decltype,
and auto

using and decltype

- In C++11, the `using` keyword has the same semantics of `typedef` specifier (alias-declaration), but with better syntax

```
typedef int distance_t; // equal to:  
using distance_t = int;
```

- In C++11, `decltype` captures the type of an object or an expression

```
int a = 3;  
decltype(a)      b = 5;    // 'b' is int  
decltype(2.0f)   c = 3.0f; // 'c' is float  
decltype(a + 2.0f) d = 3.0f; // 'd' is float  
decltype(f(a))   e = ...;  // 'e' depends on f(a)  
  
using T = decltype(a);    // T is int  
T value = 3;
```


auto Keyword

The `auto` keyword (C++11) specifies that the type of the variable will be automatically deduced by the compiler (from its initializer)

```
auto a = 1 + 2; // 1 is int, 2 is int, 1 + 2 is int!  
//    -> 'a' is "int"  
auto b = 1 + 2.0; // 1 is int, 2.0 is double. 1 + 2.0 is double  
//    -> 'b' is "double"
```

`auto` keyword can be very useful for maintainability

```
for (auto i = k; i < size; i++)  
    ...
```

On the other hand, it may make the code less readable if excessively used because of type hiding

Example: `auto x = 0;` in general makes no sense (`x` is `int`)

Math Operators

Precedence	Operator	Description	Associativity
1	a++ a--	Suffix/postfix increment and decrement	Left-to-right
2	++a --a	Prefix increment and decrement	Right-to-left
3	a*b a/b a%b	Multiplication, division, and remainder	Left-to-right
4	a+b a-b	Addition and subtraction	Left-to-right
5	<< >>	Bitwise left shift and right shift	Left-to-right
6	< <= > >=	Relational operators	Left-to-right
7	== !=	Equality operators	Left-to-right
8	&	Bitwise AND	Left-to-right
9	^	Bitwise XOR	Left-to-right
10		Bitwise OR	Left-to-right
11	&&	Logical AND	Left-to-right
12		Logical OR	Left-to-right

In general:

- **Unary** operators have higher precedence than **binary operators**
- **Standard math operators** (+, *, etc.) have higher precedence than **comparison**, **bitwise**, and **logic** operators
- **Comparison** operators have higher precedence than **bitwise** and **logic operators**
- **Bitwise** operators have higher precedence than **logic** operators

Full table

en.cppreference.com/w/cpp/language/operator_precedence

Examples:

```
a + b * 4;           // a + (b * 4)
a * b / c % d;      // ((a * b) / c) % d
a + b < 3 >> 4;     // (a + b) < (3 >> 4)
a && b && c || d;     // (a && b && c) || d
a | b & c || e && d; // ((a | (b & c)) || (e && d))
```

Important: sometimes parenthesis can make expression worldly...
but they can help!

Undefined Behavior

Expressions with undefined (implementation-defined) behavior:

```
int i = 0;
i = ++i + 2;      // until C++11: undefined behavior
                  // since C++11:  i = 3

i = 0;
i = i++ + 2;     // until C++17: undefined behavior
                  // since C++17:  i = 3

f(i = 2, i = 1); // until C++17: undefined behavior
                  // since C++17:  i = 2

i = 0;
a[i] = i++;     // until C++17: undefined behavior
                  // since C++17:  a[1] = 1

f(++i, ++i);    // undefined behavior
i = ++i + i++;  // undefined behavior

n = ++i + i;    // undefined behavior
```

Statements and Control Flow

Assignment and Ternary Operator

- Assignment special cases:

```
int a;  
int b = a = 3; // (a = 3) return value 3  
if (b = 4)     // it is not an error, but BAD programming
```

- Structure Binding declaration: C++17

```
struct A {  
    int x = 1;  
    int y = 2;  
} a;  
  
auto [x1, y1] = a;  
cout << x1 << " " << y1;
```

- Ternary operator:

```
<cond> ? <expression1> : <expression2>
```

<expression1> and <expression2> must return a value of the same type

```
int value = (a == b) ? a : (b == c ? b : 3); // nested
```


if Statement

- *Short-circuiting:*

```
if (<true expression> || array[-1] == 0)
... // no error!! even though index is -1
    // left-to-right evaluation
```

- C++17 `if` statement with *initializer*:

```
void f(int x, int y) {
    if (int ret = x + y; ret < 10)
        cout << "a";
}
```

It aims at simplifying complex statement before the condition evaluation. Available also for `switch` statements

Loops

C++ provides three kinds of loop:

- **for**

```
for ([init]; [cond]; [increment]) {  
    ...  
}
```

To use when number of iterations is known

- **while**

```
while (cond) {  
    ...  
}
```

To use when number of iterations is not known

- **do while**

```
do {  
    ...  
} while (cond);
```

To use when number of iterations is not known, but there is at least one iteration

for Loop

- C++ allows “in loop” definitions:

```
for (int i = 0, k = 0; i < 10; i++, k += 2)
    ...
```

- Infinite loop:

```
for (;;) // also while(true);
    ...
```

- Jump statements (**break**, **continue**, **return**):

```
for (int i = 0; i < 10; i++) {
    if (<condition>)
        break; // exit from the loop
    if (<condition>)
        continue; // continue with a new iteration and exec. i++
    return; // exit from the function
}
```

C++11 introduces the **range-based for loop** to simplify the verbosity of traditional **for** loop constructs. They are equivalent to the **for** loop operating over a range of values, but more **safe**

The range-based for loop avoids the user to specify start, end, and increment of the loop

```
for (int v : { 3, 2, 1 }) // INITIALIZER LIST
    cout << v << " ";    // print: 3 2 1

for (auto c : "abcd")    // RAW STRING
    cout << c << " ";    // print: a b c d

int values[] = { 3, 2, 1 };
for (int v : values)     // ARRAY OF VALUES
    cout << v << " ";    // print: 3 2 1
```

Range-based for loop can be applied in three cases:

- Fixed-size array `int array[3]` , `"abcd"`
- Branch Initializer List `{1, 2, 3}`
- Any object with `begin()` and `end()` methods

```
std::vector vec{1, 2, 3, 4};  
  
for (auto x : vec) {  
    cout << x << ", ";  
    // print: "1, 2, 3, 4"}
```

```
int matrix[2][4];  
for (auto& row : matrix) {  
    for (auto element : row)  
        cout << "@";  
    cout << "\n";  
}  
// print: @@@@  
// @@@@
```

C++17 extends the concepts of **range-based loop** for *structure binding*

```
struct A {  
    int x;  
    int y;  
};  
  
A array[10] = { {1,2}, {5,6}, {7,1} };  
for (auto [x1, y1] : array)  
    cout << x1 << "," << y1 << " "; // print: 1,2 5,6 7,1
```

C++20 Range-based loop with initializer

```
for (int i = 0; auto x : {'A', 'B', 'C'})  
    cout << i++ << ":" << x; // print: 1:A 2:B 3:C
```

C++ `switch` can be defined over `int`, `char`, `enum class`, `enum`, etc.

```
char x = ...
int y;
switch (x) {
    case 'a': y = 1; break;
    default: return -1;
}
return y;
```

Switch scope:

```
int x = 1;
switch (1) {
    case 0: int x;      // nearest scope
    case 1: cout << x; // undefined!!
    case 2: { int y; } // ok
// case 3: cout << y; // compile error
// case 4: int x;     // compile error
}
```

Fallthrough:

```
MyEnum x
int y = 0;
switch (x) {
    case MyEnum::A:           // fallthrough
    case MyEnum::B:           // fallthrough
    case MyEnum::C: return 0;
    default: return -1;
}
```

C++17 `[[fallthrough]]` attribute

```
char x = ...
switch (x) {
    case 'a': x++;
                [[fallthrough]]; // C++17: avoid warning
    case 'b': return 0;
    default: return -1;
}
```


C++20 introduces `switch` with initializer

```
switch (int i = 0; x) {  
    case 2: i += 1;  
    case 3: i += 2;  
    default: return i;  
}
```

When `goto` could be useful:

```
bool flag = true;
for (int i = 0; i < N && flag; i++) {
    for (int j = 0; j < M && flag; j++) {
        if (<condition>)
            flag = false;
    }
}
```

become:

```
for (int i = 0; i < N; i++) {
    for (int j = 0; j < M; j++) {
        if (<condition>)
            goto LABEL;
    }
}
LABEL: ;
```

Best solution:

```
bool my_function(int M, int M) {
    for (int i = 0; i < N; i++) {
        for (int j = 0; j < M; j++) {
            if (<condition>)
                return false;
        }
    }
    return true;
}
```

I COULD RESTRUCTURE
THE PROGRAM'S FLOW
OR USE ONE LITTLE
'GOTO' INSTEAD.



EH, SCREW GOOD PRACTICE.
HOW BAD CAN IT BE?

```
goto main_sub3;
```

COMPILE

