

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 makes 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`

Syntax: `<enum_class>::<enum_value>`

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

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

```
color_t color = color_t::BLUE;
```

```
fruit_t fruit = fruit_t::APPLE;
```

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

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

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

```
// int a = color_t::GREEN; // compile error!!
```

- `enum class` can be compared

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

- `enum class` does not support other operations

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

- The size of `enum class` can be set

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

- `enum class` can be converted

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

- `enum class` should be always initialized

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

```
SColors my_color; // "my_color" maybe 0!!
```

- `enum class` is automatically enumerated

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

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

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

- `enum class` can contain alias

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

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

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

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

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

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

int main() {
    Colors a{2};           // ok, equal to Colors:BLUE
    // Colors b{4};       // compile error!!
    // Colors c = {2};    // compile error!!
    Colors d = Colors{2}; // ok, equal to Colors:BLUE
}
```


Union and Bitfield

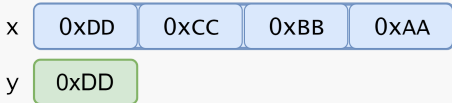
Union

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  
std::cout << a.x; // print 512 + 256 = 768
```

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

Bitfield

A **bitfield** is variable of a structure with a predefined bit width.

A bitfield can hold bits instead byte

```
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' must be int  
auto b = 1 + 2.0; // 1 is int, 2.0 is double. 1 + 2.0 is double  
//    -> 'b' must be double
```

`auto` keyword may 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

Note: `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;      // undefined behavior until C++11,
// otherwise i = 3
i = 0;
i = i++ + 2;     // undefined behavior until C++17,
// modern compilers (clang, gcc): i = 3

f(i = 2, i = 1); // undefined behavior until C++17
// modern compilers (clang, gcc): i = 2
i = 0;
a[i] = i++;     // undefined behavior until C++17
// modern compilers (clang, gcc): 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 [x, y] = a;  
cout << x << " " << y;
```

- 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 loop**

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

To use when number of iterations is known

- **while loop**

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

To use when number of iterations is not known

- **do while loop**

```
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 (;;)
    ...
```

- Jump statements:

```
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

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

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

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

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

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

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

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

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

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!!
}
```

When it is 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>) {
            flag = false;
            goto 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

