

Modern C++ Programming

3. BASIC CONCEPTS II

ENUMERATORS, STRUCTURES, AND CONTROL FLOW

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Enumerators

Enumerator

An **enumerator** `enum` is a data type that groups a set of named integral constants

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

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?
```

Strongly Typed Enumerator - enum class

enum class (C++11)

`enum class` (scoped enum) data type is a *type safe* enumerator that is not implicitly convertible to `int`

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

```
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/enum class Features

- enum/enum class can be compared
enum class does not support arithmetic operations

```
enum        color_t { RED, GREEN, BLUE };  
enum class Color { RED, GREEN, BLUE };  
cout << (Color::RED < Color::GREEN); // print true  
int  v1 = RED + GREEN; // ok  
//int v2 = Color::RED + Color::GREEN; // compile error
```

- enum/enum class are automatically enumerated in increasing order

```
enum class Color { RED, GREEN = -1, BLUE, BLACK };  
//                (0)  (-1)          (0)   (1)  
Color::RED == Color::BLUE; // true
```

- enum / enum class can contain alias

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

- `enum class` can be explicitly converted to an integer

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

- `C++11` `enum/enum class` allows to set the underlying type

```
enum class Color : int8_t { RED, GREEN, BLUE };
```

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

```
enum class Color { RED, GREEN, BLUE };  
Color a{2}; // ok, equal to Color:BLUE  
Color b{4}; // allowed but undefined behavior
```

- `C++17` `enum/enum class` supports *attributes*

```
enum class Color { RED, GREEN, [[deprecated]] BLUE };  
auto x = Color::BLUE; // compiler warning
```

C++20 allows to introduce the enumerator identifiers into the local scope to decrease the verbosity

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


enum/enum class - Common Errors

- `enum` / `enum class` should be always initialized

```
enum class Color { RED, GREEN, BLUE };
```

```
Color my_color; // "my_color" may be outside RED, GREEN, BLUE!!
```

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

```
enum Color { RED, GREEN, BLUE };
```

```
Color value = (int) 3; // undefined behavior, "value" is undefined
```

struct, Bitfield, and union

struct

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

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

`struct` / `union` without name are known as *anonymous struct* / `union`

```
struct A {  
    struct { // anonymous struct  
        int x, y;  
    };  
    char z;  
};
```

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  
    int b2 : 10; // to start at bit 32  
}; // sizeof(S1): 8 bytes
```

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

Control Flow

if Statement

The `if` statement executes the first branch if the specified condition is evaluated to `true`, the second branch otherwise

- *Short-circuiting:*

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

- *Ternary operator:*

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

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

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


for and while Loops

- **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 Features and Jump Statements

- 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 **safer**

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

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

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

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 concept of **range-based loop** for *structure binding*

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

The `switch` statement evaluates an expression (`int`, `char`, `enum class`, `enum`) and executes the statement associated with the matching case value

```
char x = ...  
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  
}
```

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;
}
```

Control Flow with Initializing Statement

Control flow with **initializing statement** aims at simplifying complex actions before the condition evaluation and restrict the scope of a variable which is visible only in the control flow body

C++17 introduces `if` statement with initializer

```
if (int ret = x + y; ret < 10)
    cout << ret;
```

C++17 introduces `switch` statement with initializer

```
switch (auto i = f(); x) {
    case 1: return i + x;
```

C++20 introduces `range-for loop` statement with initializer

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


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;  
}
```

Junior: what's wrong
with goto command?

goto command:



