

# Modern C++ Programming

## 3. BASIC CONCEPTS II

- ENTITIES AND CONTROL FLOW

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2021, v3.13



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# Enumerators

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# Enumerated Types

## 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?
```

## Enumerated Types (Strongly Typed)

`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 class` can be compared

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

- `enum class` does not support other operations

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

- `enum class` can be explicitly converted

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

- `enum class` should be always initialized

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

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

- `enum class` can contain alias

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

- `enum class` is automatically enumerated in increasing order

```
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
```



C++20 allows to introduce 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**

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

using, decltype,  
and auto

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## using and decltype

- C++11 The `using` keyword has the same semantic of `typedef` specifier (*alias-declaration*), but with a better syntax

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

- C++11 The `decltype` keyword 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;
```



**C++11** The `auto` keyword 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` 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`)

`auto` (as well as `decltype`) can be used for defining both function input C++20 and output types C++11/C++14

```
auto g(int x) -> int { return x * 2; } // C++11
// "-> int" is the deduction type
// a better way to express it is:
auto g2(int x) -> decltype(x * 2) { return x * 2; }

auto h(int x) { return x * 2; } // C++14

void f(auto x) {} // C++20
// less expensive than template
//-----
int x = g(3); // C++11

f(3); // C++20
f(3.0); // C++20
```

# Control Flow

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# if Statement

- *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
```

# 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

- 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 concept 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++ `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;
}
```

## 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:



