Notes for C and C++ programming

Tips, hints, and tricks for developers in programming C/C++.

#notes #c #c++

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Size of datatypes

The size of a type is determined by the compiler, which doesn't have anything to do with the actual hardware. The returned value of `sizeof(char)` is always 1 by definition, and `sizeof(int)` always returns 4. Starting at C99, `bool` is present as an 1-byte datatype.

Note that, size of a pointer should be 4 bytes on any 32-bit C/C++ compiler, and be 8 bytes on any 64-bit C/C++ compiler.

Use `int` instead of `char` or `uint8_t`? It depends on the target machine: if it is incapable to access unaligned memory (e.g. Cortex-M0 processors), then using `int` is much faster.

Do not use `sizeof` for array parameters

The function `fun()` below receives an array parameter `arr[]` and tries to find out the number of elements in the array `arr[]` using the `sizeof` operator. In main, there is also a statement calculating the number of elements in the array `arr[]`. But 2 methods return different results.

```
int fun(int arr[]) {
    return sizeof(arr)/sizeof(arr[0]); // WRONG
}

void main() {
    int arr[4] = {0, 0 ,0, 0};
    int arr_size = sizeof(arr)/sizeof(arr[0]); // RIGHT
    if (arr_size == fun(arr)) {} // ???
}
```

In C, array parameters are treated as pointers. So the expression:

```
sizeof(arr)/sizeof(arr[0])
```

becomes

```
sizeof(int *)/sizeof(int)
```

which finally is evaluated as `sizeof(arr) = sizeof(int *)` which is 4 or 8 depending on the compiler.

Use `goto` if it can reduce the complexity

Using `goto` is considered as bad and harmful, but if it is used with care, it can be helpful to reduce the complexity.

For example:

```
void func(...) {
    byte* buf1=malloc(...);
    byte* buf2=malloc(...);
    FILE* f=fopen(...);
    if (f==NULL)
        goto func_cleanup_and_exit;
    ...
    if (something_goes_wrong_1)
        goto func_close_file_cleanup_and_exit;
    ...

func_close_file_cleanup_and_exit:
    fclose(f);

func_cleanup_and_exit:
    free(buf1);
    free(buf2);

func_exit:
    return;
};
```

⚠ `Array[index]` is actually pointer accessing

The expression `a[i]` is translated to `*(a+i)`. That's why this weird code `printf("%c", 3["abcdef"]);` still runs.

C/C++ does not check the index range, therefore it is easy to access a memory block which is out of range of the array:

```
int a[] = {1, 2};
int b[] = {3, 4, 5};
// if a and b are allocated next to each other, b[-1] will be a[1]
printf("%d", b[-1]);
```

There are *Buffer overflow* exploiting techniques based on this problem of accessing memory block outsides of the array.

⚠ Short-circuit evaluation

At runtime, in the expression with `AND` operator `if(a && b && c)`, the part `(b)` will be calculated only if `(a)` is true, and `(c)` will be calculated only if `(a)` and `(b)` are both true.

The same story about `OR` operator: in the expression `if (a || b || c)`, if the sub-expression `(a)` is true, others will not be computed.

This helps in case the next condition depends on the previous condition, such as accessing to pointer:

```
if (pointer != NULL && pointer->member == 3) {}
```

or, checking for a higher priority condition first:

```
if (flag_a || flag_b) {}
```

However, as the consequence, do not expect the 2^{nd} or later conditions are executed in all cases.

Cached data

Modern CPUs have L1, L2, and L3 caches. When fetching data from memory, it usually read a whole line of L1 cache. For example, L1 cache has 64-bytes lines, it will fetch 64 bytes from memory at once when it accesses to a memory.

So if a data structure is larger than 64 bytes, it is very important to divide it by 2 parts: the most demanded fields and the less ones. It is desirable to place the most demanded fields in the first 64 bytes. C++ classes are also concerned.

Compiler warnings

Is it worth to turn on `-Wall` to see all possible problems which usually are small error and hard to get noticed. In GCC, it is also possible to turn all warnings to errors with `-Werror`. If enabled, any problem marked as error will halt the compiler, and it must be fixed.

Example 1:

```
int f1(int a, int b, int c) {
    int ret = a + b + c;
    printf("%d", ret);
}

int main() {
    printf("%d", f1(1,2,3));
}
```

The `main()` function still runs but prints out wrong value due to non-returned function. A random value will be seen because compiler still use the return register which is not set the desired value.

Example 2:

```
bool f1() {
    return cond ? true : false;
}
```

> `bool` is 1-byte datatype

Compiler will generate a code to set the low byte of the `AL` register to `0x01` or `0x00`, because the return size of 1 byte. Other higher bytes of the `AL` register won't change.

However, in a different file, `f1()` is assumed to return *int*, not *bool*, therefore compiler generates code to compare 4 bytes of an *int* which is only updated its lowest byte after `f1()` returns. There maybe some random value in higher bytes of that *int* memory block, and it will cause a wrong comparison:

```
void main() {
    if(f1())
}
```

Buffered `stdout` but unbuffered `stderr`

The `stdout` or `cout` is a buffered output, so a user, usually not aware of this, sees the output by portions. Sometimes, the program outputs something and then crashes, and if buffer did not have time to *flush* into the console, a user will not see anything. This is sometimes inconvenient.

Thus, for dumping more important information, including debugging, it is better to use the un-buffered `stderr` or `cerr`.

Negative error code

The simplest way to indicate to caller about its children's success is to return a boolean value: *false* — in case of error, and *true* in case of success. However, to indicate more status than just 2 states, a number can be returned. And it can be extended more to indicate different status of failure or success using signed numbers:

```
/**
* func() - A function that does something
* input:
*      none
* output:
*      -2: error on buffer
*      -1: error on transmission
*       0: success but no response
*       1: success with a response = NACK
*       2: success with a response = ACK
*/
```

Bit fields

A very popular thing in C, and also in programming generally is working with bits. For flags specifying, in order to not make a typo and mess, they can be defined using bit shifting:

```
#define FLAG1 (1<<0)
#define FLAG2 (1<<1)
#define FLAG3 (1<<2)
#define FLAG4 (1<<3)
#define FLAG5 (1<<4)
```

and some macros can be use to work on bits:

```
#define IS_SET(flag, bit) (((flag) & (bit)) ? true : false)
#define SET_BIT(var, bit) ((var) |= (bit))
#define REMOVE_BIT(var, bit) ((var) &= ~(bit))
```

For better performance, use *bool* for each bit, but it will cost memory.