VE280 Programming and Elementary Data Structures

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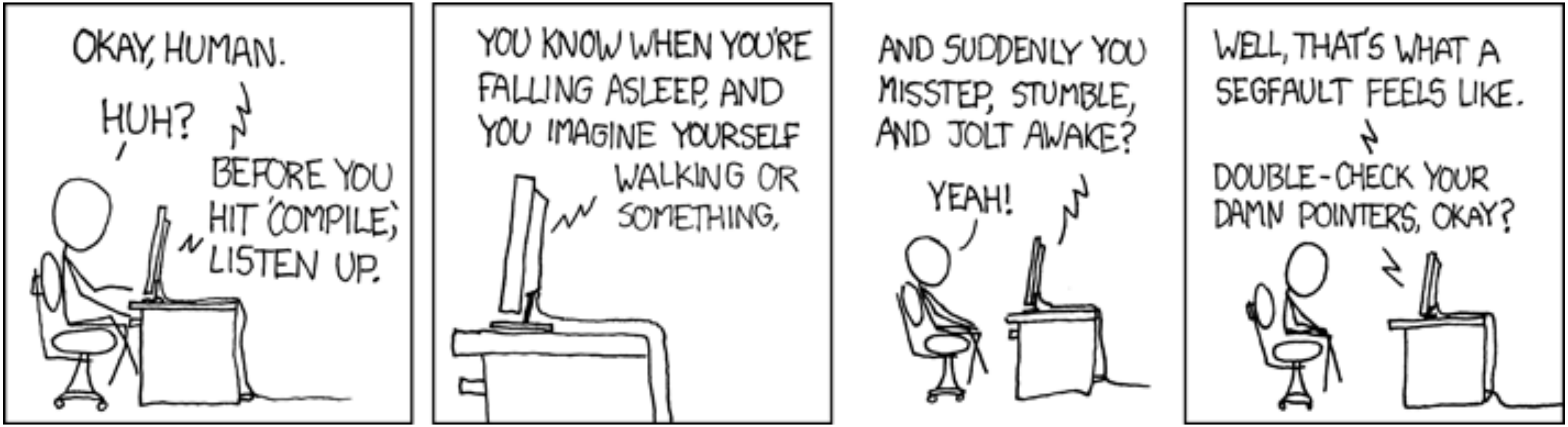
const and constexpr Qualifiers; typedef



Learning Objectives

- Understand what is the const qualifier and when to use it
  - Know what a const reference is
  - Know the difference between a const pointer and a pointer to a const
- Understand what is the constexpr qualifier
- Know how to use typedef

const Qualifier

- Often, a numerical value in a program could have some valid meaning.

```
char name[256];
```

The max size of name string

- Also, that value with the same meaning may appear many times in the program

```
for(i=0; i < 256; i++) ...
```

- If we only use 256, it has two drawbacks
  - The readability is bad.
  - If we need to update max size of a name string from 256 to 512, we need to examine each 256 (some may have other meanings) and update the corresponding ones.
    - It takes time and is error-prone!

const Qualifier

- Instead of just using 256, define a constant, and use the constant:

```
const int MAXSIZE = 256;
char name[MAXSIZE];
```

- Usually, constant is defined as a global variable.
- Property
  - Cannot be modified later on
  - Must be initialized when it is defined

```
const int a = 10;
a = 11; // Error
```

```
const int i;
// Error
```

const Reference

```
const int iVal = 10;
const int &rVal = iVal;
```

- Furthermore, const reference can be initialized to an rvalue

```
const int &ref = 10; // OK
const int &ref = iVal+10; // OK
```

- In contrast, nonconst reference cannot be initialized to an rvalue

```
int &ref = 10; // ERROR
int &ref = iVal+10; // ERROR
```

Practical Use of const Reference

- One popular use of const reference: pass struct/class as the function argument

```
int avg_exam(const struct Grades & gr){
   return (gr.midterm+gr.final)/2;
}
```

- In comparison:

```
int avg_exam(struct Grades gr) {...}
```

Problem? Pass-by-value can be **expensive**, particularly for large structures.

```
int avg_exam(struct Grades & gr) {...}
```

Problem? It allows for the possibility of (mistakenly) changing the contents of the **caller's** `gr`.

Practical Use of const Reference

- One popular use of const reference: pass struct/class as the function argument

```
int avg_exam(const struct Grades & gr){
   return (gr.midterm+gr.final)/2;
}
```

- Advantages of using const reference as argument
  - We don't have the expense of a copy.
  - We have the safety guarantee that the function cannot change the caller's state.

Practical Use of const Reference

- Compared with non-const reference, another advantage is function call with consts or expressions is OK
  - In contrast, for non-const reference, function call with consts or expressions is not OK

```
foo("Hello world!")
```

```
void foo(string & str) {...}
```

versus

```
void foo(const string &str) {...}
```

const Pointers

- When you have pointers, there are two things you might change:
  1. The value of the pointer.
  2. The value of the object to which the pointer points.

- Either (or both) can be made unchangeable:

```
const T *p;  // "T" (the pointed-to object)
pointer to const  // cannot be changed by pointer p
T *const p;  // "p" (the pointer) cannot be
const pointer  // changed
const T *const p; // neither can be changed.
```

Pointers to const

Example

```
int a = 53;
const int *cptr = &a;
   // OK: A pointer to a const object
   // can be assigned the address of a
   // nonconst object
*cptr = 42;
   // ERROR: We cannot use a pointer to
   // const to change the underlying
   // object.
a = 28 // OK
int b = 39;
cptr = &b; // OK: the value in the pointer
           // can be changed.
```

const Pointers

Example

```
int a = 53;
int *const cptr = &a;
  // OK: initialization
*cptr = 42;
  // OK: We can use a const pointer to
  // change the underlying object.
int b = 39;
cptr = &b;
  // ERROR: We cannot change the value of
  // a const pointer.
```

Define Pointers to const Using typedef

- Recall typedef: gives an alias to the existing types:

  ```
  typedef existing_type alias_name;
  ```

  - Example: `typedef int * intptr_t;`

    Then we can use it: `intptr_t ip;`

- Use `typedef` to define pointer to const:
  - ```
    typedef const T constT_t;
    typedef constT_t * ptr_constT_t;
    ```
  - Now `ptr_constT_t` is an alias for the type of `const T *` pointer to const
    ```

How do we use `typedef` to rename the type of `T *const`?

const pointer

Select all the correct answers.

- **A.** `typedef const T const_t;`
  `typedef const_t *constptrT_t;`
- **B.** `typedef T *ptrT_t;`
  `typedef ptrT_t const constptrT_t;`
- **C.** `typedef const * constptr_t;`
  `typedef constptr_t T constptrT_t;`
- **D.** `typedef T * const constptrT_t;`

Practical Use of Pointer to const

Example

```
void strcpy(char *dest, const char *src)
   // src is a NULL-terminated string.
   // dest is big enough to hold a copy of src.
   // The function place a copy of src in dest.
   // src is not changed.
{ ... }
```

- Strictly speaking, we don't **need** to include the `const` qualifier here since the comment promises that we won't modify the source string
- So, why include it?

Practical Use of Pointer to const

Example

- Why include `const`?

- Because once you add it, you CANNOT change `src`, even if you do so by mistake.
- Such a mistake will be caught by the **compiler**.
  - Bugs that are detected at compile time are among the easiest bugs to fix – those are the kinds of bugs we want.

- **General guideline**: Use `const` for things that are passed by reference, but won't be changed.

Pointer to const versus Normal Pointer

- Pointers-to-const-T are not the same type as pointers-to-T.
- You can use a pointer-to-T anywhere you expect a pointer-to-const-T, but NOT vice versa.

```
int const_ptr(const int *ptr)
{
    …
}

int main()
{
    int a = 0;
    int *b = &a;
    const_ptr(b);
}
```

```
int nonconst_ptr(int *ptr)
{
    …
}

int main()
{
    int a = 0;
    const int *b = &a;
    nonconst_ptr(b);
}
```

Pointer to const versus Normal Pointer

- Why can you use a pointer-to-T anywhere you expect a pointer-to-const-T?
  - Code that expects a pointer-to-const-T will work perfectly well for a pointer-to-T; it's just guaranteed not to try to change it.

- Why **cannot** you use a pointer-to-const-T anywhere you expect a pointer-to-T?
  - Code that expects a pointer-to-T might try to change the T, but this is illegal for a pointer-to-const-T!

Variable `x` is declared as being of type `const T * const`.

Select all the correct answers.

- **A.** My code cannot change `x` (using `x`).
- **B.** My code cannot change the value pointed by `x` (using `x`).
- **C.** `x` may change while the program is running.
- **D.** The value pointed by `x` may change while the program is running.

constexpr Qualifier

- A constant expression is a value known at compilation time
- Use `constexpr`, e.g.,

```
constexpr int n=10;
constexpr int m=n+10;
int a[m];
```

- Only literal types are allowed: bool, char, int, long…
- References and pointers can be `constexpr`
- But more complex types cannot, e.g., string, classes…
- `constexpr` variables are `const`

Pointers with constexpr

- **Watch out!** Compare the following two lines:
  - `const int *p = nullptr;`
  - `constexpr int *q = nullptr;`
  - p is a pointer to a const int vs q is a const pointer to int

- Illustrative example:
  - `int j = 0; // outside any function`
  - `constexpr int i = 4; // outside any fun.`
  - `constexpr const int *p = &i;`

  `// p: a constant pointer to the const int i`
  - `constexpr int *p1 = &j;`

  `// p1: a constant pointer to the int j`

Reference

- const and constexpr Qualifiers
  - C++ Primer, 4^{th} Edition, Chapter 2.4
- typedef
  - C++ Primer, 4^{th} Edition, Chapter 2.5