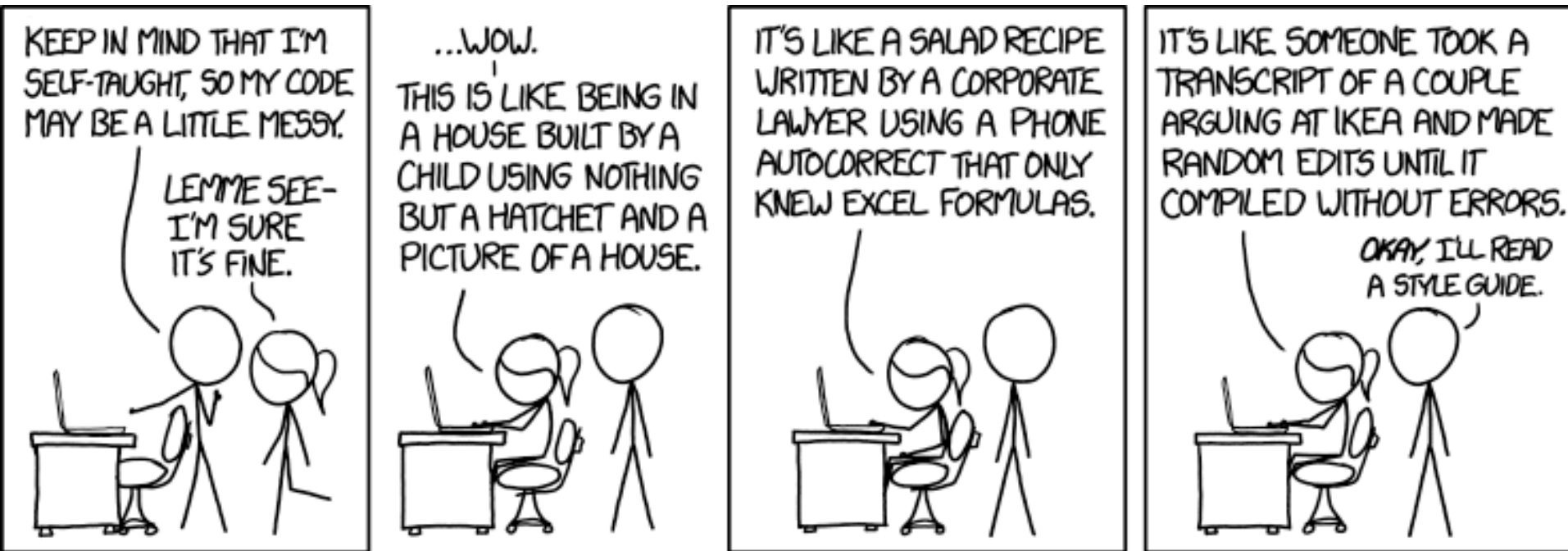


VE280 Programming and Elementary Data Structures

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Midterm Review



Midterm

- 16:00 – 17:40, June 25st, 2023
- Close book
- For all students: in-person (rooms announced soon)
- Except for those outside Shanghai: Feishu (link shared soon)
- Personal work is expected
 - No communication allowed

Midterm

- Written exam
 - A number of questions which only require you to provide a very short answer
 - A few questions which require you to write code.
- Abide by the **Honor Code!**

Midterm Topics

- Linux Commands
- Compiling and Developing Program on Linux
- C++ Basics: Pointers, References, const Qualifier
- Procedural Abstraction and Specification Comments
- Recursion
- Function Pointers
- enum Type
- Program Taking Arguments
- I/O Streams
- Testing/Debugging
- Exception
- Class Basics

Lecture 1 to this lecture

Linux Commands

- `cd; ls; mkdir; rmdir;`
- `cp; mv; rm;`
- `nano; gedit; vim;`
- `cat; less;`
- `diff; man; ...`
- I/O redirection
 - `<, >`
- Command options
 - `ls -l; cp -r dir1 dir2; ...`
- Wildcard: `*`
 - `cp *.h dir/`

Compiling Program on Linux

- Write the source code, for example, using **gedit**
- Compile the program: **g++ -o program source.cpp**
- Run the program: **./program**
- Compile multiple source files:
 - **g++ -o program src1.cpp src2.cpp src3.cpp**
 - E.g., **g++ -o run_add run_add.cpp add.cpp**
- Header guard: avoiding multiple inclusions

```
// add.h
#ifndef ADD_H
#define ADD_H
int add(int a, int b);
#endif
```

- What happens if the .h file is included **first** time?
- What happens if the .h file is included **second** time?

A Better Way of Compiling: Makefile

`all: run_add`

- The file name is “**Makefile**”
- Type “**make**” on command-line

`run_add: run_add.o add.o`

`g++ -o run_add run_add.o add.o`

`run_add.o: run_add.cpp`

`g++ -c run_add.cpp`

`add.o: add.cpp`

`g++ -c add.cpp`

`clean:`

`rm -f run_add *.o`

A Rule

Target: Dependency
<Tab> Command



Don't forget the Tab!

Dependency: A list of files
that the target depends on

Function Call Mechanisms

There are two function call mechanisms:

1. Call-by-value
2. Call-by-reference

What will a be?

```
void f(int x) {  
    x *= 2;  
}
```

```
void f(int& x) {  
    x *= 2;  
}
```

```
int main() {  
    ...  
    int a=4;  
    f(a);  
    ...  
}
```

```
int main() {  
    ...  
    int a=4;  
    f(a);  
    ...  
}
```


Pointers

```
int foo = 1;
```

```
int *bar;
```

```
bar = &foo; // addressing operation
```

```
*bar = 2; // dereference operation
```

0x804240c0 foo:

A diagram illustrating memory layout. It consists of a large outer rectangle containing two horizontal boxes. The top box is preceded by the text '0x804240c0 foo:' and the bottom box by '0x804240e4 bar:'. Both boxes are empty, representing memory locations for variables.

0x804240e4 bar:

A diagram illustrating memory layout. It consists of a large outer rectangle containing two horizontal boxes. The top box is preceded by the text '0x804240c0 foo:' and the bottom box by '0x804240e4 bar:'. Both boxes are empty, representing memory locations for variables.

References

- An alternative name for an object

```
int iVal = 1024;  
int &refVal = iVal;
```

- Reference **must be initialized** using a **variable** of the same type.

References Versus Pointers

Example

```
int x = 0;  
int &r = x;  
int y = 1;  
r = y;  
r = 2;
```

What are the final values
of x, y, and r?

x = 2, y = 1, r = 2

```
int x = 0;  
int *p = &x;  
int y = 1;  
p = &y;  
*p = 2;
```

What are the final values
of x, y, and *p?

x = 0, y = 2, *p = 2

const Qualifier

- Once you defined a constant variable, it cannot be modified later on.

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

- Because we cannot subsequently change the value of an object declared to be const, we must initialize it when it is defined:

- `const int i;`
`// Error: i is an uninitialized const`

const Reference

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

- It gives us the best of both worlds:
 - We don't have the expense of a copy.
 - We have the safety guarantee that the function cannot change the caller's state. Compiler will catch the error of accident change!

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.
```



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);  
}
```



Abstraction

- Abstraction
 - Provides only those details that matter.
 - Eliminates unnecessary details and reduces complexity.
- Example: Multiplication algorithm
 - Many ways to do: table lookup, summing, etc.
 - Each looks quite different, but they do the **same** thing.
 - In general, a user won't care how it's done, just that it multiplies.

Procedural Abstraction

- Two important properties of procedural abstraction
 - **Local**: the implementation of an abstraction does not depend on any other abstraction implementation.
 - **Substitutable**: you can replace one (correct) implementation of an abstraction with another (correct) one, and no callers of that abstraction will need to be modified.

Procedural Abstraction

Specification Comments

- We describe procedural abstraction by specification comments.
- There are three clauses of specification comments:
 - **REQUIRES**: the pre-conditions that must hold, if any.
 - **MODIFIES**: how inputs are modified, if any.
 - **EFFECTS**: what the procedure computes given legal inputs.
- Note that the first two clauses have an “**if any**”, which means they may be empty, in which case you may omit them.

Call Stacks

How a function call really works

- When a function is called, an activation record (also known as stack frame) is created. It holds the function's **formal parameters** and **local variables**.
- The **activation record** for **the current** invocation is added to the “top” of the stack.
- When that function returns, its **activation record** is removed from the “top” of the stack.



double add(double a, double b): a = 1, b = 0, result = 0

double sin(double x): x = 1, result = 0

int main(): x = 1, sinResult = 0

Recursion

$$n! = \begin{cases} 1 & (n == 0) \\ n * (n-1)! & (n > 0) \end{cases}$$

```
int factorial (int n) {  
    // REQUIRES: n >= 0  
    // EFFECTS:  computes n!  
1.    if (n == 0) {  
2.        return 1;    // 'base case'  
3.    } else {  
4.        return n*factorial(n-1); // 'recursive  
step'  
5.    }  
6. }
```

Recursion

Writing a function for the general case

- Treat it like an inductive proof.
- To write a correct recursive function, do two things:
 1. Identify the “trivial” case (or cases), and write them explicitly.
 2. For all other cases, first assume there is a function that can solve smaller versions of the same problem, then figure out how to get from the smaller solution to the bigger one.

Recursive Helper Function

- Sometimes it is easier to find a recursive solution to a problem if you change the original problem slightly, and then solve that problem using a **recursive helper function**.

```
soln() {  
    ...  
    soln_helper();  
    ...  
}
```

```
soln_helper() {  
    ...  
    soln_helper();  
    ...  
}
```


Function Pointers

Motivation

- If you were asked to write a function to add all the elements in a list, and another to multiply all the elements in a list, your functions would be almost exactly **the same**.
- Writing almost the exact same function twice is almost certainly a bad idea

Function pointers to the rescue!

Function Pointers

A first look

```
int min(int a, int b);  
    // EFFECTS: returns the smaller of a and b.  
int max(int a, int b);  
    // EFFECTS: returns the larger of a and b.
```

- These two functions have precisely the same type signature:
 - They both take two integers, and return an integer.
- Of course, they do completely different things:
 - One returns a min and one returns a max.
 - **However, from a syntactic point of view, you call either of them the same way.**

Function Pointers

Basic Format

- Declaration

```
int    (*foo) (int, int);
```

- Once defined, we can assign it to a function that has **the same type signature**

```
int min(int a, int b);  
foo = min;
```

- Furthermore, after assigning min to foo, we can just call it as follows:

```
foo(3, 5)
```

...and we'll get back 3!

Enum Type

- Define an enumeration type as follows:

```
enum Suit_t {CLUBS, DIAMONDS,  
             HEARTS, SPADES};
```

- Define variables of this enum type:

```
enum Suit_t suit;
```

- You can initialize them as:

```
enum Suit_t suit = DIAMONDS;
```

- Once you have such an enum type defined, you can use it as an argument for a function.

Enum Type

- If you write

```
enum Suit_t {CLUBS, DIAMONDS,  
             HEARTS, SPADES};
```

then numerically

```
CLUBS = 0, DIAMONDS = 1,  
HEARTS = 2, SPADES = 3
```

- Using this fact, it will sometimes make life easier

```
enum Suit_t s = CLUBS;  
const string suitname[] = {"clubs",  
                           "diamonds", "hearts", "spades"};  
cout << "suit s is " << suitname[s];
```

Passing Arguments to a Program

- Programs can take arguments.

diff file1 file2

- Arguments are passed to the program through `main()` function.
- We need to change the argument list of `main()`:
 - `int main(int argc, char *argv[])`
- `argv` stores the array of C-strings that user inputs.
 - `argv[0]` is the name of the program being executed.
- `argc` is the number of strings in the array

I/O Streams

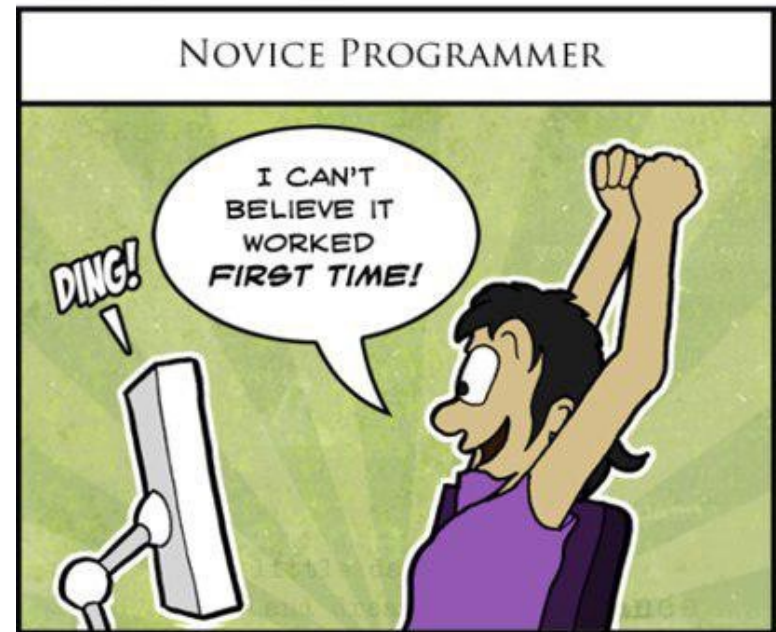
- Output Stream `cout`
 - Insertion operator `<<`
- Input Stream `cin`
 - extraction operator `>>`
 - `getline(cin, str)`
 - `cin.get(ch)`
 - Failed input stream: check stream state `if (cin)`
- `cout` and `cin` streams are buffered.

I/O Streams

- File Stream
 - `ifstream; ofstream`
 - Opening a file: `ifstream.open("myText.txt");`
 - extraction `>>` ; insertion `<<`
- String Stream
 - `istringstream; ostream`
 - extraction `>>` ; insertion `<<`
 - Assign a string to an input string stream
`istream.str(line);`
 - fetch the string value from an output string stream
`ostream.str();`

Testing

- Be skeptical!
- Incremental testing
- Five Steps:
 1. Understand the specification
 2. Identify the required behaviors
 3. Write specific tests
 - **Simple inputs**
 - **Boundary conditions**
 - **Nonsense**
 4. Know the answers in advance
 5. Include stress tests



Debugging Using Assert

- Using the `assert` function
 - The `assert` function is a special function, which takes a Boolean argument.
 - If the argument is **true**, `assert()` does nothing.
 - If the argument is **false**, `assert()` causes your program to stop, printing an **error message** to the `cerr` stream.
- `assert` for the condition that should hold.

Exceptions

- Exceptions and exception handling mechanism



- **Exception propagation** mechanism: where to find the handler

Exceptions

Exception Handling

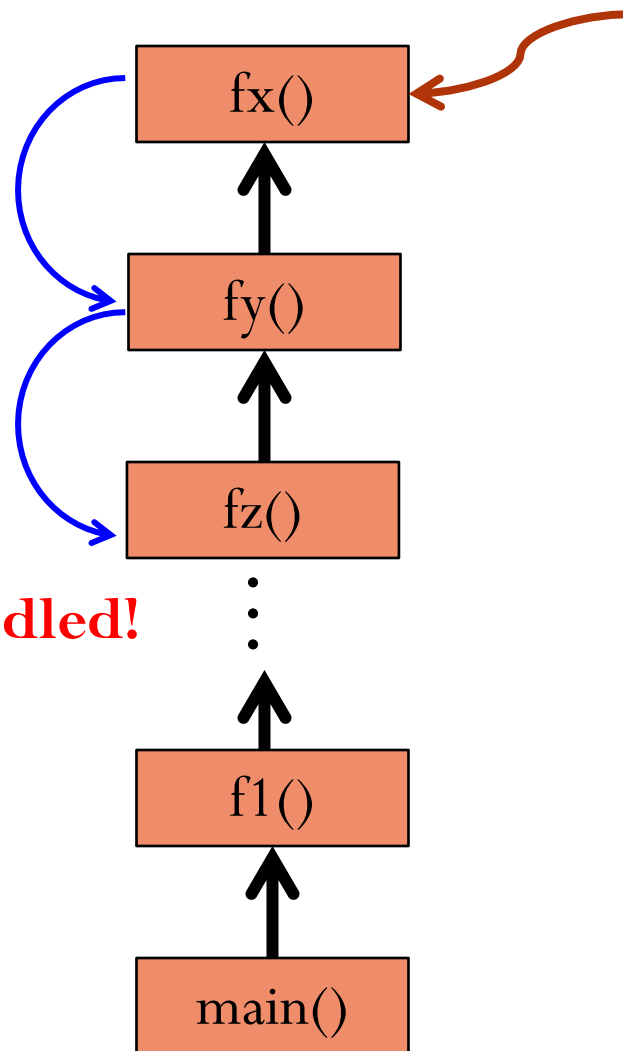
handler in fx()? **No!**

handler in fy()? **No!**

handler in fz()? **Yes!**

Exception handled!

**exception
occurs**



Exceptions

- Throwing an exception
- Catching an exception
- Exceptions have **types** and **objects**.
 - **throw** **errorObj**;
- Exceptions Handling in C++

```
void foo () {  
    try {  
        catch (Type var) {  
    }  
}
```

Abstract Data Types

- The role of a type:
 - The set of values that can be represented by items of the type
 - The set of operations that can be performed on items of the type.
- An abstract data type provides an **abstract description** of **values** and **operations**.
- Advantages: Information hiding and encapsulation.

C++ Classes

- Data members and function members are defined in a single entity.
- **Public** versus **private** members.
- Defining a class type.
- Class object as a function argument: pass by value

C++ Classes

- **Constructor** for initialization: `IntSet () ;`

- Initialization syntax:

```
IntSet::IntSet () : numElts (0)
{ }
```

- const member function: `int size() const;`
 - Means: the member function **size()** cannot change the object on which **size()** is called.
 - Syntax: if a const member function calls other **member** functions, they must be **const** too!

```
void A::g() const { f(); }
```

```
void A::f() { ... } ❌
```

```
void A::f() const { ... } ✅
```