CS202: Programming Systems

Week 8: Exception Handling

11/2022

CS202 – What will be discussed?

- Introduction
- try-throw-catch
- RAII

Introduction: some ways to handle errors

- Terminate the program immediately
- Return a special value to represent that the program got some errors
- Return a normal value but change the state of the whole program to “error state”
- Invoke a certain function when there is any error

[1] terminate immediately

- It is not a good way to do because most of the times, we can handle the error and continue the program instead of just simply terminate the running program

[2] return a **special** value

- The **special** value is not always possible to represent. In some cases, the function might take all the range of the possible values. Thus, there is no special value to represent it.
- Also, you need to check it every time you invoke the function
- Or, the function may not have a return
  - E.g. constructors

An example

- You have to check every time → makes the program bigger and harder to maintain

```
int main()
{
    //...
    fd=open("file",O_RDWR);
    if(fd==-1)
       ...
}
```

[3] return a normal value but change the state of the program to “error state”

- The caller might not notice the program has been put into “error state”
- In C language, many libraries have used this method and change the global variable **`errno`** to a special value. It is hard to keep checking this value to know if there is an error.
- It is also not suitable for parallel processing applications

Exception handling

- It is a simple but powerful technique in C++ to help you handle errors.
- Exception handling allows you to separate the error handling section from the normal program

Exception handling

- C++ provides a mechanism via try-throw-catch to handle exceptions

```
void f1() {
   if(...)
      throw “something wrong”;
};
int main(){
   try {
      f1();
   }
   catch(char* s) {
      cout << “Error: "<< s << endl;
   }
   return 0;
};
```

An example: **`x*y/(x-y)`**

```
double calc(double x, double y) {
    if(x == y)
        throw “divide by zero”;
    return x*y/(x-y)
};
int main(){
    double a, b;
    ...
    try {
        a = calc(a, b);
    }
    catch(char* s) {
        cout << “Error: "<< s << endl;
    }
    return 0;
};
```

```
class bad_index{};
class no_memory{};
void test()
{
   if(...)
      throw bad_index();
   if(...)
      throw no_memory();
}
int main() {
   ...
   try {
      test();
   }
   catch(bad_index& bi){
       ...
   }
   catch (no_memory& nm){
      ...
   }
}
```

different exception class to differentiate errors

throw exception

catch and handle

`catch`

- `catch` can access and change the value of the exception variables but all changes are just local within exception blocks (even passed by references)
- If `throw` in the `try{}` block doesn’t return any value, the `catch` block will not be processed. Instead, the program will be terminated.

`catch`

- There must be at least 1 **`catch`** block right after each **`try{}`**
- **`catch`** has many arguments with their data types to receive the return values of **`throw`** from **`try{}`**.
- **`catch`** is only executed only when there is a **`throw`** with return value from **`try{}`**.

`catch`: matching algorithms

```
void test() {
   try {
      throw E();
   }
   catch (H) {
      //when it comes here???
   }
```

1. H has the same type as E
2. H is a base class of E
3. H & E are pointers and (1) or (2) satisfies
4. H is a reference and (1) or (2) satisfies

`catch(...)`

- **`catch(...)`** will catch any return values of throw
- It is often used as the last **`catch`** block to capture remaining exceptions.

`catch`

- Within the **`catch`** block, we can throw the exception to higher levels:
  - Throw with new operands with their data types
  - Throw with no operand. It means the catch throw the exception it received again to higher level.

After being throw

- If it couldn’t find a matched catch block to the throw operand, the **unwinding stack** will be executed until there is a matched catch block.
- If it still couldn’t find any matched catch block, the program will be terminated.

`throw` declaration for a function

- By default: a function can throw anything
- To specify certain types of **`throw`** for a function, it is declared at the end of the function declaration

For example:

```
int foo(int x) throw(char, int);
```

- If we declare **`int foo(int x) throw();`** the function does NOT expect to throw anything

Some issues of exception handling

- Memory leak if we couldn’t handle resources properly.
- Exception handling does NOT work well with templates because template function might throw different exceptions based on different type parameters.

An example of memory leaking

```
int doSomething(int size)
{
   int* arrTest;
   arrTest = new int[size];
   ...
   if (condition)
     throw bad_exception();
   ...
   delete [] arrTest;
   return 0;
}
```

Another example

```
MyStr& MyStr::operator=(const MyStr& src)
{
   if (this == &src)
      return *this;
   delete [] s;
   if (src.s)
   {
      s = new char [strlen(src.s) + 1];
      strcpy (s, src.s);
   }
   else s = NULL;
   return *this;
}
```

`throw` an error

A fix for it

```
MyStr& MyStr::operator=(const MyStr& src) {
    if (this == &src)
        return *this;
    char* tmpS;
    if (src.s) {
        tmpS = new char [strlen(src.s) + 1];
        strcpy (tmpS, src.s);
    }
    else tmpS = NULL;
    delete [] s;
    s = tmpS;
    return *this;
}
```

Some questions!!!

- How can we handle if the constructors have errors/exceptions?
- How can we catch exceptions from initialization list?
- Nested **`try{}`** block
- Inheritance and polymorphism of exception classes?
- Why do we have **`void pop()`** for a stack?

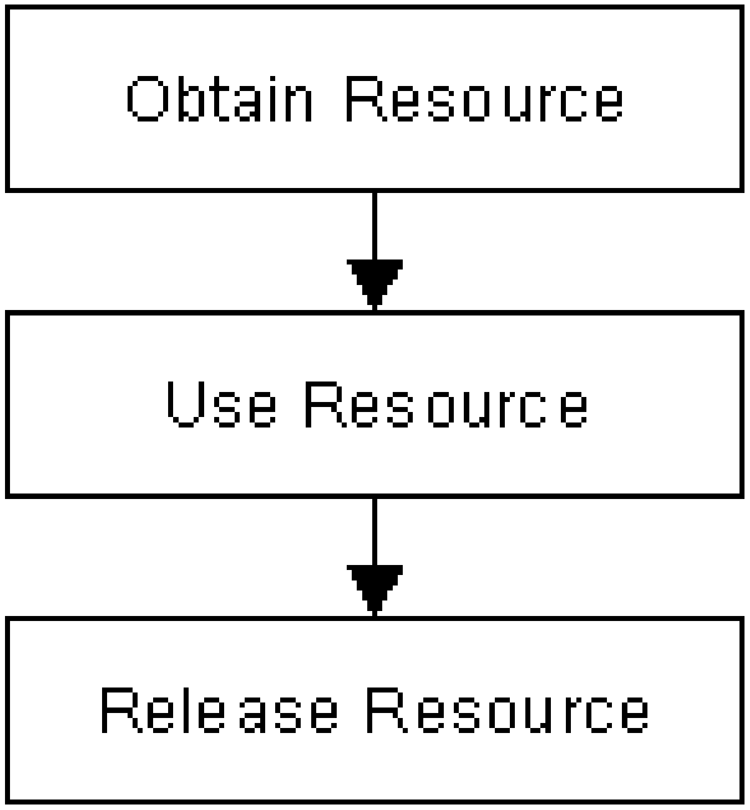
RAII: Resource Acquisition Is Initialization

- Invented by Bjarne Stroustrup to ensure that if a resource is used, it is released properly by attaching it into the life cycle of the object.
- RAII helps to write exception-safe code easier.

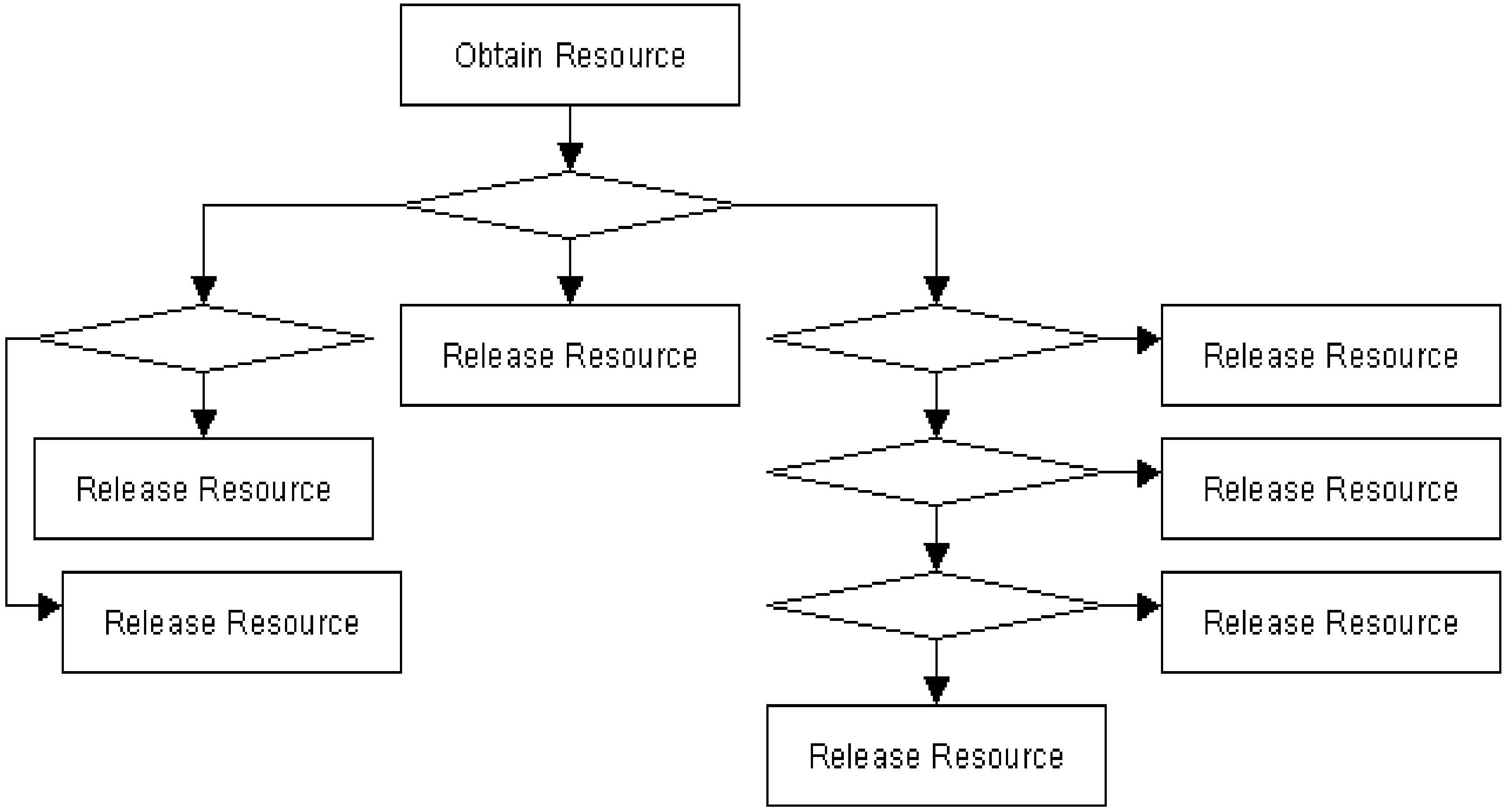
Main applications of RAII

- Often used to manage thread lock of multi-threading applications.
- Applications working with resources, such as dynamic memory allocating or file management to avoid leaking.

Problem



Problems become more complex



```
#include <cstdio>
class file {
public:
   file (const char* filename):
     f(std::fopen(filename, "w+")){
        if (!f)
         throw std::runtime_error("open failure");
   }
   ~file(){
          if (0 != std::fclose(f))
               {... } // handle it
   }
   void write (const char* str);
}
private:
   std::FILE* f;
   ...
};
```

(from wikipedia)

Using the file class above

```
void example_usage()
{
    // open file (acquire resource)
    file logfile("logfile.txt");
    logfile.write("hello logfile!");
   // continue using logfile ...
   // throw exceptions or return
       // without worrying about closing the log;
   // it is closed automatically when out of scope
}
```