The Big Three

C++ Object Oriented Programming

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Contents

Introduction

- When the class has the functionality of resource management, it is very likely that the destructor (dtor), the copy constructor (copy ctor), and the assignment operator occur together.
- Resource management: ex. **called the BIG 3**

```
class Account {
public:
   Account(const char *name, const char *phone, const char *address);
   ~Account();
   ….
private:
   char *m_name;
   char *m_phone;
   char *m_address;
};
```

remote ownership

```
Account::Account(const char *name, const char *phone, const char *address) {
   m_name = new char[strlen(name)+1]; strcpy(m_name, name);
   m_phone = new char[strlen(phone)+1]; strcpy(m_phone, phone);
   m_address = new char[strlen(address)+1]; strcpy(m_address, address);
}
```

dtor

```
Account::~Account() {
   delete[] m_name; delete[] m_phone; delete[] m_address;
}
```


Copy Constructor (copy ctor)

- What is a copy constructor? X(X&)

  Account(Account &src); and Account(const Account &src);
- When is the copy constructor invoked? **when the object is copied**

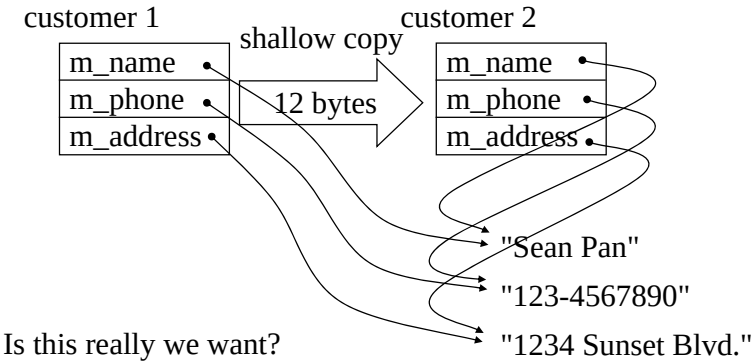
Case 1:
```
Account customer1("Sean Pan",
                  "123-4567890", "1234 Sunset Blvd.");
Account customer2(customer1);
Account customer3 = customer1;
```

Case 2:
```
void fun1(Account customer) {
   …
}
```

Case 3:
```
Account fun2() {
   Account x;
   …
   return x;
}
```

Copy Constructor

- If you do not define the copy constructor, the compiler will synthesize one for your class. This copy constructor copies all the bits in the object to initiate the new object. For many cases this implementation does the right thing, but for a class which allocates memory or handles other resources itself, this usually leads to errors.



Is this really we want?

Problems: Dangling Reference

- Consider the following function call

```
void fun(Account customerLocal) {
    ….
} // the dtor would deallocate the memory belongs to customerLocal
  //  however, these memory blocks are the same as those of customer

void main() {
   Account customer("Sean Pan", "123-4567890", "1234 sunset Blvd.");
      …
   fun(customer);
      …
   customer.display(); // show all the customer information
}
```

- At the above line, the statement fun(customer) would cause *dangling reference* and the statement customer.display() would access memory blocks previously belonged to this customer object and display some strange contents.

Problems: Unexpected Release

- Sometimes, the resource might be unexpectedly released, ex.

```
void readFile(ifstream is) {   // VC 2010 compiler does not allow this
…
}
void main() {
   ifstream infile("input.dat");
   …
   readFile(infile);
   …
}
```

- This is a complex problem. The program will have runtime error. Why does the error occurs? You won't be able to correct this by supplying a copy constructor for ifstream because it is a library class. The only thing you can easily do is not invoking the copy ctor by passing the parameter with reference.

Example Copy Constructor

```
Account::Account(Account &src) {
   m_name = new char[strlen(src.m_name)+1];
   strcpy(m_name, src.m_name);
   m_phone = new char[strlen(src.m_phone)+1];
   strcpy(m_phone, src.m_phone);
   m_address = new char[strlen(src.m_address)+1];
   strcpy(m_address, src.m_address);
}
```

- Copy ctor is a kind of ctor. You should use initialization list whenever possible. Especially, you should invoke the base class copy ctor if it is a derived class.
- In a copy ctor, you are creating an object. The memory space for the object itself is just allocated by system, the ctor need to initialize it.
- If you would like to prevent public use of call-by-value semantics of a certain object, you can declare a dummy copy ctor in the private section of the class.

Member Object and Base Class

- Copy constructor is a constructor, member objects and base class must be initialized through initialization list
- For example:

```
class Derived: public Base
{
public:
   …
   Derived(Derived &src);
   …
private:
   Component m_obj;
};
Derived::Derived(Derived &src): Base(src), m_obj(src.m_obj) {
   …
}
```

Compiler adds **Base()** invocation automatically

Note:

```
Derived::Derived(Derived &src)
      : m_obj(src.m_obj)
{
   …
}
```

both are chained automatically

Assignment Operator

- Where is the assignment operator invoked?

```
Account customer1("abc", "1234", "ABC street");
Account customer2, customer3;  // assume default ctor defined
customer2 = customer1;
customer2.operator=(customer1);
customer3 = customer2 = customer1;
```

- Note: Account customer2 = customer1;
  does not invoke the assignment operator
- What is its prototypes?

```
Account &operator=(Account &rhs);
```

Designed for continuously assignment

No extra copy ctor invoked

```
customer3.operator=(customer2.operator=(customer1));
```

Note: this does not contradict the rule that reference does not bind to temporary object

Assignment Operator

- Again, if the class being designed allocates its own resources. It is quite often to see the dtor, copy ctor, and the assignment operator occur together.
- There are seven important things to do in an assignment operator

```
Account &Account::operator=(Account &rhs)
{
① if (&rhs == this) return *this;
② delete[] m_name;  delete[] m_phone;  delete[] m_address;
③ m_name = new char[strlen(rhs.m_name)+1];
  m_phone = new char[strlen(rhs.m_phone)+1];
  m_address = new char[strlen(rhs.m_address)+1];
④ strcpy(m_name, rhs.m_name);
  strcpy(m_phone, rhs.m_phone);
  strcpy(m_address, rhs.m_address);
⑤ // invoke the base class assignment operator
⑥ // invoke the component object assignment operator
⑦ return *this;
}
```

Detecting self assignments

Assignment Operator

- You can declare the assignment operator in the private section to prevent public usage of the assignment semantics.
- If there is a reference variable or a const variable defined in the class, there is no way to define the assignment operator.
- Usually, the assignment operator repeats the codes both in the copy ctor and the dtor. It is common to prepare common functions to be called in assignment operator, copy ctor and the dtor.
- These 3 are never inherited because based class functions are not sufficient to initialize, copy, or destroy a derived instance.
- Again, three make a team. Do not forget any one of them.

Managed Pointer

- Standard template class auto_ptr<T>: #include <memory>

  auto_ptr<Fred> acts like a Fred* except that **it owns the referent** (the Fred object)

  1. You can declare a managed pointer with NULL value initially
     auto_ptr<Fred> ptr;
  2. You can invoke the assignment operator later
     ptr = auto_ptr<Fred>(new Fred());
  3. You can also construct a pointer with
     auto_ptr<Fred> ptr(new Fred()); or
     auto_ptr<Fred> ptr = new Fred();
  4. This object can be used anywhere like a Fred* pointer.
     ptr–>services();
     *ptr.services();
     Fred *ptrRaw = ptr.get();

ptr now owns this new Fred object

Managed Pointer (cont'd)

5. Copy ctor is implemented with **ownership transfer** (surprise!!)
   auto_ptr<Fred> newPtr = ptr; // or
   auto_ptr<Fred> newPtr(ptr);
6. When this object goes out of scope, the dtor will delete the owned Fred object.
7. What about an explicit delete?
   delete ptr; // syntax error, do not new an auto_ptr, do not keep the raw Fred pointer, pass by reference to a function
8. If you copy the managed pointer from another managed pointer without ownership to the real object, the new managed pointer does not have ownership to the real object. If you construct a new managed pointer with a raw pointer twice, both objects have ownership. Fortunately, delete in its dtor will only succeed once. But using a pointer without ownership to the real object is likely to be a dangling reference like a raw pointer.

newPtr now owns the Fred object originally owned by ptr, ptr will point to the same object afterwards but do not own it anymore.

Managed Pointer (cont'd)

- auto_ptr is part of C++98, C++03 and is more commonly called a **smart pointer**, do not get confused with **operator->** overloading
- **auto_pt**r implements copy and assignment **with implicit ownership transfer** due to the lack of ***move semantics*** in C++98/03. The compiler allows you to pass an auto_ptr by value to a function, the original auto_ptr would lose the ownership and ① the managed resource is going to be deleted as the function exits unless another auto_ptr is returned back. auto_ptr ② cannot manage an array and ③ cannot be used in a container.
- Do not use auto_ptr!!
- The following smart pointers are designed to replace it
  - boost::shared_ptr, boost::scope_ptr, boost::shared_array, boost::scopy_array, boost::weak_ptr
  - C++0x, C++11: std::shared_ptr, std::weak_ptr, std::unique_ptr