Copy Semantics

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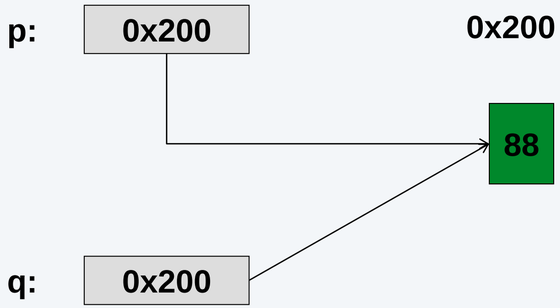
SHALLOW COPY VS. DEEP COPY

Old School Memory: Shallow Copy

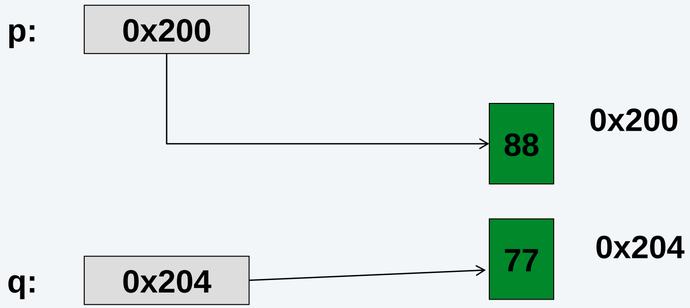


SHALLOW COPY

```
int main()
{
  int *p = new int{77};
  int *q = p;
  *p = 88;
}
```

Reference: Bjarne Stroustrup. 2014. Programming: Principles and Practice Using C++ (2nd. ed.). Addison-Wesley Professional, pg. 637.

Old School Memory: Deep Copy




```
int main()
{
  int *p = new int{77};
  int *q = new int{*p};
  *p = 88;
}
```

DEEP COPY

Reference: Bjarne Stroustrup. 2014. Programming: Principles and Practice Using C++ (2nd. ed.). Addison-Wesley Professional, pg. 637.

Unique Pointer: NO Shallow Copy!

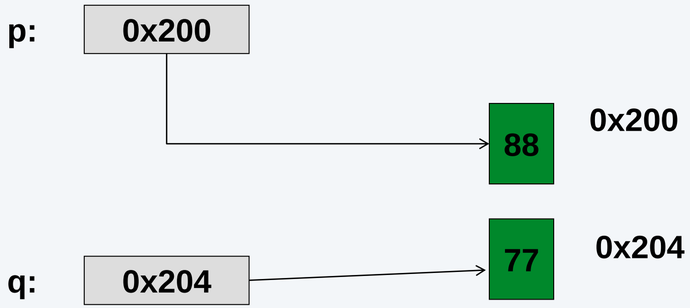
```
#include <memory>
using namespace std;

int main()
{
  unique_ptr<int> p = make_unique<int>(77);
  unique_ptr<int> q = p; // Will not compile
  *p = 88;
}
```

No copying or assigning unique pointers:

Only one unique pointer may manage one physical address!

Unique Pointer: Deep Copy




```
#include <memory>
using namespace std;

int main()
{
  unique_ptr<int> p = make_unique<int>(77);
  unique_ptr<int> q = make_unique<int>(*p);
  *p = 88;
}
```

DEEP COPY

Struct/Class Assignment

By default assigning or copying a struct or class object to another of the same type performs **shallow copy.**

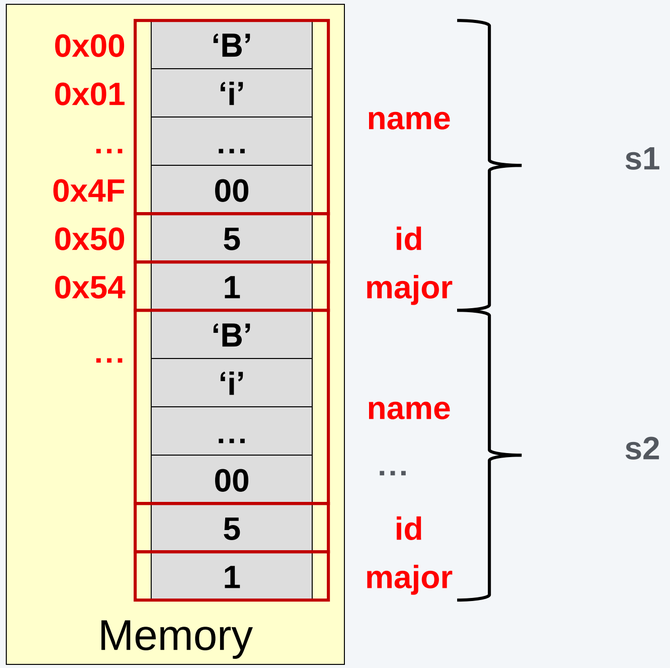
This is element by element copy of the source struct/class to the destination struct/class

```
#include<iostream>
using namespace std;

enum {CS, CECS };

struct student {
  char name[80];
  int id;
  int major;
};

int main(int argc, char *argv[])
{
  student s1,s2;
  strncpy(s1.name,”Bill”,80);
  s1.id = 5; s1.major = CS;
  s2 = s1;
  return 0;
}
```



COPY CONSTRUCTORS

Copy Constructors

A **copy constructor is** constructor that makes a new object from an object of the same type.

Most common prototype:

ClassName(const ClassName& c);

Default copy constructor makes shallow copy.

If deep copy necessary, such a copy constructor must be defined.

```
class Complex
{
 public:
  Complex();
  Complex(double r, double i);
  Complex(const Complex& c);

 private:
  double real, imag;
};

int main()
{
  Complex c1(2,3), c2(4,5)
  Complex c3(c1);
  Complex c4 = c2;


}
```

Calls to Copy Constructor

When an object is **passed by value**, a copy of the object is made by the copy constructor.

When an object is **returned by value**, a copy is made by the copy constructor.

```
class Complex
{
 public:
  Complex();
  Complex(double r, double i);
  Complex(const Complex &c)
  ~Complex();
  private:
  double real, imag;
};
// Copy constructor
Complex::Complex(const Complex &c)
{
  cout << "In copy constructor" << endl;
  real = c.real; imag = c.imag;
}
// ** Copy constructor called for pass-by-value
Complex f1(Complex rhs)
{
   cout << "In f1" << endl;
   return rhs;

}

int main()
{
  Complex c1(2,3), c2(4,5);
  Complex x = f1(c1);
  //     ** Copy Constructor called on c1 **

}
```

Default Copy Constructors

C++ compiler automatically generates a ***default*** copy constructor

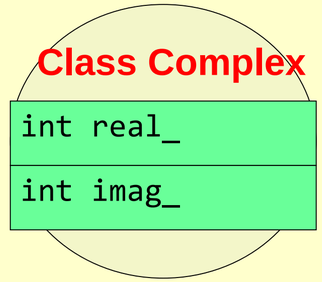
- **Simply performs an element by element copy**
- Provides shallow copy

```
class Complex
{
 public:
  Complex(double r, double i);
  // compiler will provide by default:
  // Complex(const Complex& );
  // Complex& operator=(const Complex&);
  ~Complex()
 private:
  double real, imag;
};


int main()
{
  Complex c1(2,3), c2(4,5)

  Complex c3(c1); // copy constructor
  Complex c4 = c1; // copy constructor


}
```



Defining Copy Constructors

Let's examine the deep copy constructor for Str.

```
#include <memory>
#include <string.h>

class Str {
    public:
    Str();
    Str(const Str& other);
    Str(const char* s);
    size_t size() const;
    // other member functions

    private:
    std::unique_ptr<char []> buffer;
    size_t len;

};

Str::Str(const Str& other){

   buffer = std::make_unique<char[]>(other.size()+1);
   len = other.size();
   strcpy(this->buffer.get(), other.buffer.get());

}
int main()
{
  Str s1("hello");
  Str s2(s1); // Str s2 = s1;
}
```

COPY ASSIGNMENT

Copy Assignment

The copy assignment operator, `operator=()`, is called when an object already exists and then another object of the same type is assigned to it.

Prototype:

ClassName& operator=(const ClassName& c);

C++ compiler automatically generates a ***default*** copy assignment operator

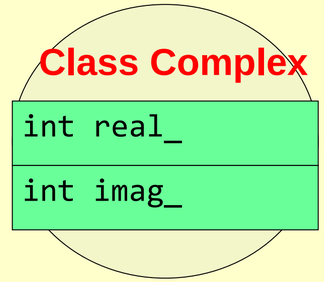
- **Simply performs an element by element copy**
- **Only shallow copy**

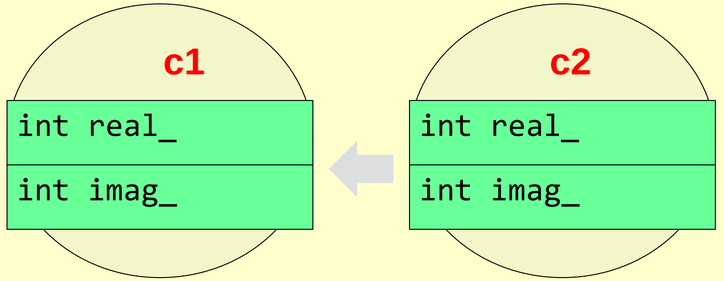
If deep copy necessary, such a copy assignment operator must be defined.

```
class Complex
{
 public:
  Complex(double r, double i);
  // compiler will provide by default:
  // Complex(const Complex& );
  // Complex& operator=(const Complex&);
  ~Complex()
 private:
  double real, imag;
};


int main()
{
  Complex c1(2,3), c2(4,5)
  c1 = c2;   // default assignment oper.
  // c1.operator=(c2)

}
```





Copy Assignment Operator Details

RHS should be a const reference

Return value should be a reference

- Allows for chained assignments
- Should return (*this)

```
class Complex
{
 public:
  Complex(int r, int i);
  ~Complex()
  Complex operator+(Complex right_op);
  Complex& operator=(const Complex &rhs);
 private:
  int real, imag;
};


Complex& Complex::operator=(const Complex & rhs)
{
   real = rhs.real;
   imag = rhs.imag;
   return *this;
}

int main()
{
  Complex c1(2,3), c2(4,5);

  Complex c3, c4;
  c4 = c3 = c2;
  // same as c4.operator=( c3.operator=(c2) );
}
```

Assignment Operator Overloading

The = operator can be overloaded with different types

```
class Complex
{
 public:
  Complex(int r, int i);
  ~Complex();
  Complex operator+(const Complex &rhs);
  Complex &operator=(const Complex &r);
  Complex &operator=(const int r);
  int real, imag;
};

Complex& Complex::operator=(const int& r)
{
  real = r; imag = 0;
  return *this;
}

int main()
{
  Complex c1(3,5);
  Complex c2,c3,c4;
  c2 = c4 = 5;
  // c2 = (c4 = 5) ;
  // c4.operator=(5);  // Complex::operator=(int&)
  // c2.operator=(c4); // Complex::operator=(Complex&)
  return 0;
}
```

Defining Copy Assignment Operators

Let's examine the deep copy assignment operator for Str.

```
#include <memory>
#include <string.h>

class Str {
    public:
    Str();
    Str(const Str& other);
    Str(const char* s);
    size_t size() const;
    Str& operator=(const Str& rhs);
    // other member functions
    private:
    std::unique_ptr<char []> buffer;
    size_t len;

};

Str& Str::operator(const Str& rhs){
   if (&rhs == this) return *this;
   buffer = std::make_unique<char[]>(rhs.size()+1);
   len = rhs.size();
   strcpy(this->buffer.get(), rhs.buffer.get());
   return *this;
}
int main()
{
  Str s1("hello");
  Str s2("world");
  s2 = s1;
}
```

Assignment Operator Tips

Copy Assignment operator input is const reference of the same object type

Copy Assignment operators should check for initialized members and check for self-assignment

Assignment operators should return a reference type and return *this

When to Manage Copy Semantics

Default copy constructor and assignment operator ONLY perform SHALLOW copies

- **SHALLOW COPY (data members only)**
- **DEEP copy (data members + what they point at)**

You SHOULD define your own copy constructor and assignment operator when a DEEP copy is needed

- When data members are pointers to data that should be copied when a new object is made
- Often if your data members are pointing to dynamically allocated data, you need a DEEP copy

If a Shallow copy is acceptable, you do NOT need to define a copy constructor

For shallow copies, a default copy constructor and default assignment operator are sufficient

Rule of Three:

- If memory is dynamically allocated (deep copy needed), implement a **copy constructor**, an **assignment operator**, and a **destructor**

Rule of Zero:

- Whenever possible design your classes so that they do not need to define the default constructor, destructor, copy constructor, and copy assignment.