CS 247: Software Engineering Principles

Special Member Functions

Readings:  Eckel, Vol. 1
    Ch. 11  References and the Copy Constructor
    Ch. 12  Operator Overloading (operator= )
Special Member Functions

C++ member functions that are so important that the compiler will provide default versions if we don't provide them:

- default constructor (0 parameters; generated iff we define *no* constructor)
- destructor
- copy constructor
- copy assignment (\(\text{operator=}\))
- move constructor
- move assignment
If we do not declare any constructor for our class, the compiler will generate a default constructor for us: based on *memberwise initialization*.

- **simple data members (built-in types):** uninitialized
- **pointer members:** uninitialized
- **member objects:** initialized using members' default constructors
- **inherited members:** initialized using base class default constructor
If we do not declare a destructor for our class, the compiler will generate a destructor for us: based on **memberwise destruction**

- **simple data members**: deallocated
- **pointer members**: pointer deallocated (*not deleted*)
- **member objects**: cleaned up using members' destructors
- **inherited members**: cleaned up using base class's destructor
Copy Constructor

A **copy constructor** constructs a new object whose value is equal to an existing object.
- Used by the compiler to copy objects of the ADT.

```cpp
class Money;

Money operator+ (Money m, Money n);

int main() {
    Money m;       // 1
    Money n{m};    // 2
    Money p = m;   // 3
    p = p + n;     // 4 & 5
}
```
Shallow copy copies the object and its pointers' addresses, so that the original and copied pointers refer to the same object.

Deep copy copies the object and what its pointers point to, so that the pointer data members refer to distinct objects.
If we do not provide a default constructor or copy/move constructor or copy/move assignment, the compiler will generate a copy constructor for us: based on memberwise copy

- **simple data members**: bitwise copy
- **pointer members**: bitwise copy
- **member objects**: copied using members' copy constructors
- **inherited members**: copied using base class's copy constructor
Copy Assignment Operator

Copy assignment is similar to the copy constructor, except that the destination of the copy already exists.

\[ X = Y; \quad // \text{deep copy} \]
If we do not provide a copy/move constructor or copy/move assignment, the compiler will create a copy operator member function for us: based on **memberwise assignment**:

- **simple data members**: bitwise copy
- **pointer members**: bitwise copy
- **member objects**: uses members' assignment operators
- **inherited members**: uses base class's assignment operator

X = Y;  // shallow copy
Copy-Swap Idiom

Assignment operators may deal with pointer members by:
- creating a new object of the same type with the copy constructor,
- swapping the old values of the pointer members with the values in the newly created object,
- letting the destructor take care of deleting the old members,
- but at the cost of efficiency!!

```cpp
// friend that swaps contents of m1 and m2
// using std::swap from <algorithm>
void swap( MyClass & m1, MyClass & m2 ) {
    Base &b_m1 = static_cast<Base&>(m1);
    Base &b_m2 = static_cast<Base&>(m2);
    swap( b_m1, b_m2 );
    std::swap( m1.comp_, m2.comp_ );
    std::swap( m1.ptr_, m2.ptr_ );
    std::swap( m1.simple_, m2.simple_ );
}

MyClass& MyClass::operator=( const MyClass& m ) {
    MyClass temp{m};
    swap( *this, temp );
    return *this;
}
```
A **move constructor** constructs a new object whose value is equal to an existing object, but does not preserve the value of the existing object.

```cpp
MyClass::MyClass (MyClass&& m) :
   Base{ std::move(m) },
   comp_{ std::move(m.comp_) },
   simple_{ m.simple },
   ptr_{ m.ptr_ } {
      m.ptr_ = nullptr;
}
```

To invoke members’ move constructor, need to pass an *rvalue reference* created by `std::move()`.

Only requirement of moved-from object is that it be easy to delete and (copy) reassign. *What does this imply?*
If we do not provide a default constructor or copy/move constructor or copy/move assignment, then the compiler will generate a move constructor for us: based on memberwise move

- **simple data members**: bitwise copy
- **pointer members**: bitwise copy
- **member objects**: uses members' move/copy constructors
- **inherited members**: uses base class's move/copy constructor
Move Assignment

Move assignment is similar to the move constructor, except that the destination of the move already exists.

Only requirement of moved-from object is that it be easy to delete and (copy) reassign.

```cpp
MyClass& MyClass::operator= (MyClass&& m) {
    MyClass temp(0);
    swap( temp, m ); // temp steals m’s contents
    swap( *this, temp ); // put what used to be in m into this

    return *this;
}
```
We can improve the code by passing the argument by value and **unifying** the copy assignment and move assignment operators into a single member method. Compiler will call this assignment operator even with an rvalue.

```cpp
MyClass::MyClass( const MyClass & other) : MyClass(0) {
    copy( *this, other );
}

MyClass::MyClass( MyClass && other ) : MyClass(0) {
    swap( *this, other );
}

MyClass& MyClass::operator= (MyClass m) {
    swap( *this, m );
    return *this;
}
```
If we do not provide a copy/move constructor or copy/move assignment, the compiler will create a move operator member function for us: based on memberwise move assignment:

- **simple data members**: bitwise copy
- **pointer members**: bitwise copy
- **member objects**: uses members' move/copy assignment
- **inherited members**: uses base class's move/copy assignment

```
X = Y;  // shallow copy
```
## Special Members

A table showing the default, compiler implicitly declared, and user declared status for special members:

<table>
<thead>
<tr>
<th>user declares</th>
<th>default constructor</th>
<th>destructor</th>
<th>copy constructor</th>
<th>copy assignment</th>
<th>move constructor</th>
<th>move assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nothing</td>
<td>defaulted</td>
<td>defaulted</td>
<td>defaulted</td>
<td>defaulted</td>
<td>defaulted</td>
<td>defaulted</td>
</tr>
<tr>
<td>Any constructor</td>
<td>not declared</td>
<td>defaulted</td>
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<td>defaulted</td>
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<tr>
<td>default constructor</td>
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<tr>
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Equality

A copied/assigned object should be equal ( operator== ) to the original.

Deep equality

Shallow equality

The compiler does NOT generate a default version of the equality operator—we are on our own.
bool operator==( const MyClass &m, const MyClass &m2 )
{
    if ( !( Base::operator==(m, m2) ) ) return false;

    if ( m.simple_ != m2.simple_ ) return false;

    if ( ! (m.comp_ == m2.comp_) ) return false;

    if ( !m.p_ && !m2.p_ ) return true;

    if ( !m.p_ || !m2.p_ ) return false;

    return *m.p_ == *m2.p_ ;
}
Take Aways

Recognition
• C++ special member functions (6 of them):
  if one needs to be hand-crafted, likely all of them do

Comprehension
• Best practices for ADT design
• Entity vs. Value-based ADTs
• Rules for compiler-default special member functions (default constructor, destructor, copy constructor, copy assignment)

Application
• Operator overloading
• Const function arguments and member functions
• ADT design (entity vs. value-based design, immutable ADTs, hidden implementation)
• User-defined constructors, destructor, copy constructor, copy assignment