auto_ptr, unique_ptr, shared_ptr and weak_ptr

Prerequisite – Smart Pointers

3.9

C++ libraries provide implementations of smart pointers in following types:

- auto_ptr
- unique_ptr
- shared_ptr
- weak_ptr

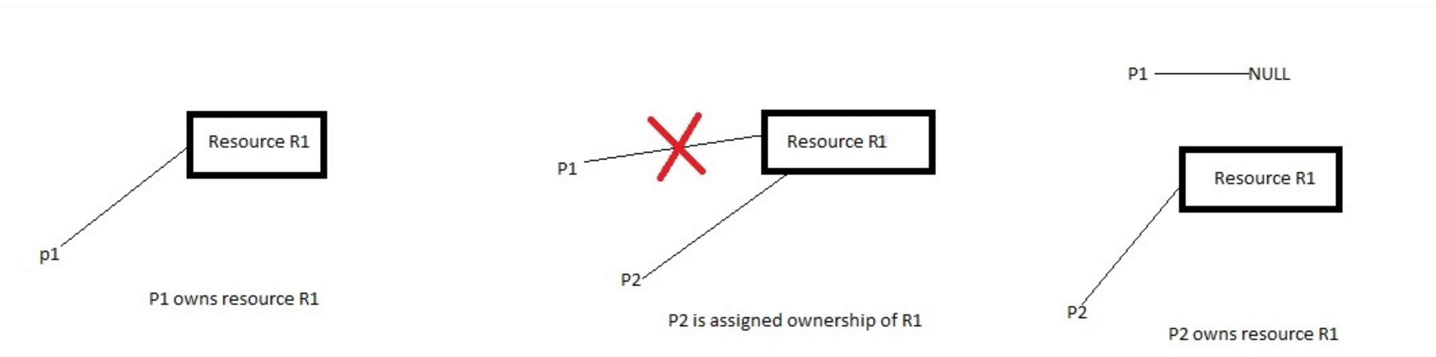
They all are declared in memory header file.

auto_ptr

This class template is deprecated as of C++11. **unique_ptr** is a new facility with a similar functionality, but with improved security.

auto_ptr is a smart pointer that manages an object obtained via new expression and deletes that object when auto_ptr itself is destroyed.

An object when described using auto_ptr class it stores a pointer to a single allocated object which ensures that when it goes out of scope, the object it points to must get automatically destroyed. It is based on **exclusive ownership model** i.e. two pointers of same type can't point to the same resource at the same time. As shown in below program, copying or assigning of pointers changes the ownership i.e. source pointer has to give ownership to the destination pointer.




```
// C++ program to illustrate the use
#include<iostream>
#include<memory>
using namespace std;

class A
{
public:
    void show() {  cout << "A::show(
};

int main()
{
    // p1 is an auto_ptr of type A
    auto_ptr<A> p1(new A);
    p1 -> show();
```

```
    // returns the memory address of
    cout << p1.get() << endl;

    // copy constructor called, this
    auto_ptr <A> p2(p1);
    p2 -> show();

    // p1 is empty now
    cout << p1.get() << endl;

    // p1 gets copied in p2
    cout<< p2.get() << endl;

    return 0;
}
```

Run on IDE

Output:

```
A::show()
0x1b42c20
A::show()
0
0x1b42c20
```

The copy constructor and the assignment operator of auto_ptr do not actually copy the stored pointer instead they transfer it, leaving the first auto_ptr object empty. This was one way to implement strict ownership, so that only one auto_ptr object can own the pointer at any given time i.e. auto_ptr should not be used where copy semantics are needed.

Why is auto_ptr deprecated?

It takes ownership of the pointer in a way that no two pointers should contain the same object. Assignment transfers ownership and resets the rvalue auto pointer to a null pointer. Thus, they can't be used within STL containers due to the aforementioned inability to be copied.

unique_ptr

std::unique_ptr was developed in C++11 as a replacement for std::auto_ptr.

unique_ptr is a new facility with a similar functionality, but with improved security (no fake copy assignments), added features (deleters) and support for arrays. It is a container for raw pointers. It explicitly prevents copying of its contained pointer as would happen with normal assignment i.e. it allows exactly one owner of the underlying pointer.

So, when using unique_ptr there can only be at most one unique_ptr at any one resource and when that unique_ptr is destroyed, the resource is automatically claimed. Also, since there can only be one unique_ptr to any resource, so any attempt to make a copy of unique_ptr will cause a compile time error.

```
unique_ptr<A> ptr1 (new A);

// Error: can't copy unique_ptr
unique_ptr<A> ptr2 = ptr1;
```

But, unique_ptr can be moved using the new move semantics i.e. using std::move() function to transfer ownership of the contained pointer to another unique_ptr.

```
// Works, resource now stored in ptr2
unique_ptr<A> ptr2 = move(ptr1);
```

So, it’s best to use unique_ptr when we want a single pointer to an object that will be reclaimed when that single pointer is destroyed.

```
// C++ program to illustrate the use
#include<iostream>
#include<memory>
using namespace std;

class A
{
public:
    void show()
    {
        cout<<"A::show()"<<endl;
    }
};

int main()
{
    unique_ptr<A> p1 (new A);
    p1 -> show();

    // returns the memory address of
    cout << p1.get() << endl;

    // transfers ownership to p2
    unique_ptr<A> p2 = move(p1);
    p2 -> show();
    cout << p1.get() << endl;
    cout << p2.get() << endl;

    // transfers ownership to p3
    unique_ptr<A> p3 = move (p2);
    p3->show();
    cout << p1.get() << endl;
    cout << p2.get() << endl;
    cout << p3.get() << endl;

    return 0;
}
```

Run on IDE

Output:

```
A::show()
0x1c4ac20
```

```
A::show()
0          // NULL
0x1c4ac20
A::show()
0          // NULL
0          // NULL
0x1c4ac20
```

The below code returns a resource and if we don't explicitly capture the return value, the resource will be cleaned up. If we do, then we have exclusive ownership of that resource. In this way we can think of unique_ptr as safer and better replacement of auto_ptr.

```
unique_ptr<A> fun()
{
    unique_ptr<A> ptr(new A);

    /* ...
       ... */

    return ptr;
}
```

When to use unique_ptr?

Use unique_ptr when you want to have single ownership(Exclusive) of resource. Only one unique_ptr can point to one resource. Since there can be one unique_ptr for single resource its not possible to copy one unique_ptr to another.

shared_ptr

A shared_ptr is a container for raw pointers. It is a **reference counting ownership model** i.e. it maintains the reference count of its contained pointer in cooperation with all copies of the shared_ptr. So, the counter is incremented each time a new pointer points to the resource and decremented when destructor of object is called.

Reference Counting: It is a technique of storing the number of references, pointers or handles to a resource such as an object, block of memory, disk space or other resources.

An object referenced by the contained raw pointer will not be destroyed until reference count is greater than zero i.e. until all copies of shared_ptr have been deleted.
So, we should use shared_ptr when we want to assign one raw pointer to multiple owners.

```
// C++ program to demonstrate shared
#include<iostream>
#include<memory>
using namespace std;

class A
{
public:
    void show()
    {
```

```
        cout<<"A::show()"<<endl;
    }
};

int main()
{
    shared_ptr<A> p1 (new A);
    cout << p1.get() << endl;
    p1->show();
    shared_ptr<A> p2 (p1);
    p2->show();
    cout << p1.get() << endl;
    cout << p2.get() << endl;

    // Returns the number of shared_
    //referring to the same managed
    cout << p1.use_count() << endl;
    cout << p2.use_count() << endl;

    // Relinquishes ownership of p1
    //and pointer becomes NULL
    p1.reset();
    cout << p1.get() << endl;
    cout << p2.use_count() << endl;
    cout << p2.get() << endl;

    return 0;
}
```

Run on IDE

Output:

```
0x1c41c20
A::show()
A::show()
0x1c41c20
0x1c41c20
2
2
0          // NULL
1
0x1c41c20
```

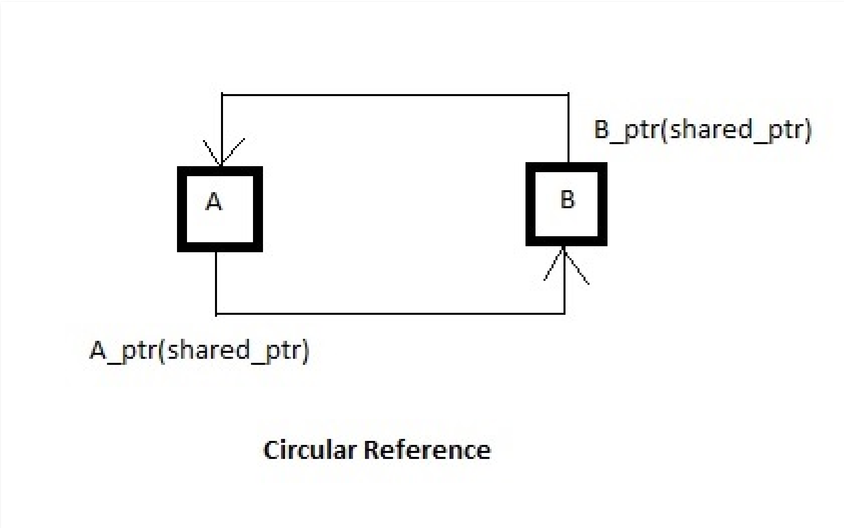
When to use shared_ptr?

Use shared_ptr if you want to share ownership of resource . Many shared_ptr can point to single resource. shared_ptr maintains reference count for this propose. when all shared_ptr's pointing to resource goes out of scope the resource is destroyed.

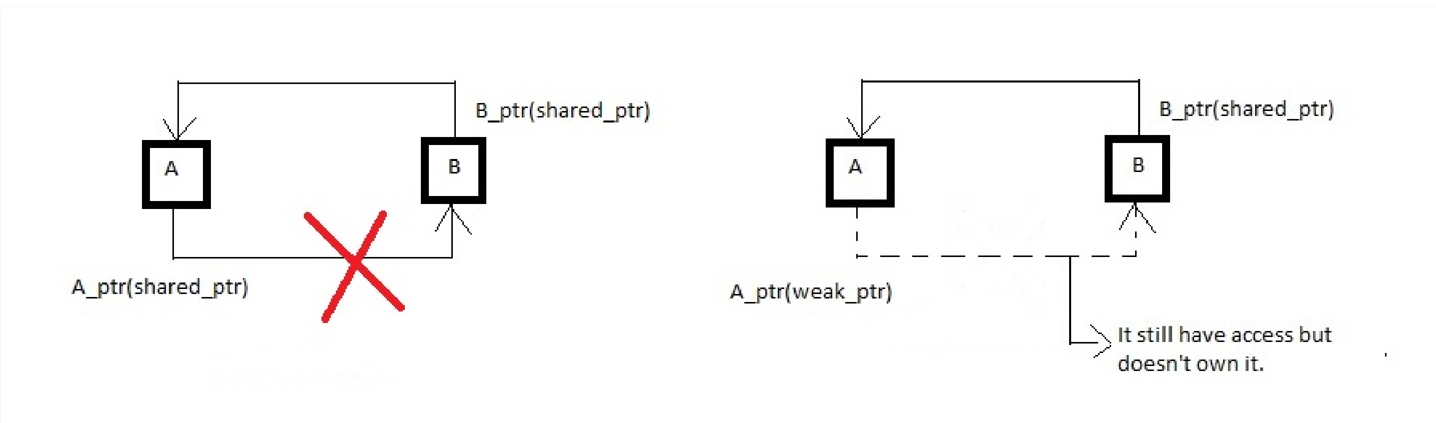
weak_ptr

A weak_ptr is created as a copy of shared_ptr. It provides access to an object that is owned by one or more shared_ptr instances, but does not participate in reference counting. The existence or destruction of weak_ptr has no effect on the shared_ptr or its other copies. It is required in some cases to break circular references between shared_ptr instances.

Cyclic Dependency (Problems with shared_ptr): Let’s consider a scenario where we have two classes A and B, both have pointers to other classes. So, it’s always be like A is pointing to B and B is pointing to A. Hence, use_count will never reach zero and they never get deleted.



This is the reason we use **weak pointers**(weak_ptr) as they are not reference counted. So, the class in which weak_ptr is declared doesn’t have strong hold of it i.e. the ownership isn’t shared, but they can have access to these objects.



So, in case of shared_ptr because of cyclic dependency use_count never reaches zero which is prevented using weak_ptr, which removes this problem by declaring A_ptr as weak_ptr, thus class A does not own it, only have access to it and we also need to check the validity of object as it may go out of scope. In general, it is a design issue.

When to use weak_ptr?

When you do want to refer to your object from multiple places – for those references for which it’s ok to ignore and deallocate (so they’ll just note the object is gone when you try to dereference).