Smart Pointers

Dr. Anwar Shah, PhD, MBA(HR)
Assistant Professor in CS
FAST National University of Computer and Emerging Sciences CFD

Section Overview

Smart Pointers

- Issues with raw pointers
- What are smart pointers?
- Concept of ownership and RAII
- C++ Smart Pointers
  - Unique pointers (`unique_ptr`)
  - Shared pointers (`shared_ptr`)
  - Weak pointers (`weak_ptr`)
- Custom deleters

Some Issues with Raw Pointers

Smart Pointers

Issues with Raw Pointers

- C++ provides absolute flexibility with memory management
  - Allocation
  - Deallocation
  - Lifetime management
- Some potentially serious problems
  - Uninitialized (wild) pointers
  - Memory leaks
  - Dangling pointers
  - Not exception safe
- Ownership?
  - Who owns the pointer?
  - When should a pointer be deleted?

What is Smart Pointer, Ownership and RAII

Smart Pointers

What are they?

- Objects
- Can only point to heap-allocated memory
- Automatically call delete when no longer needed
- Adhere to RAII principles
- C++ Smart Pointers
  - Unique pointers (`unique_ptr`)
  - Shared pointers (`shared_ptr`)
  - Weak pointers (`weak_ptr`)
  - Auto pointers (`auto_ptr`) **Deprecated** – we will not discuss

Smart Pointers

What are they?

- `#include <memory>`

- Defined by class templates
  - Wrapper around a raw pointer
  - Overloaded operators
    - Dereference (`*`)
    - Member selection (`->`)
    - Pointer arithmetic not supported (`++`, `--`, etc.)
  - Can have custom deleters

Smart Pointers

A simple example

```
{
    std::smart_pointer<Some_Class> ptr = . . .

    ptr->method();
    cout << (*ptr) << endl;
}

// ptr will be destroyed automatically when
// no longer needed
```

Smart Pointers

RAII – Resource Acquisition Is Initialization

- Common idiom or pattern used in software design based on container object lifetime
- RAII objects are allocated on the stack
- Resource Acquisition
  - Open a file
  - Allocate memory
  - Acquire a lock
- Is Initialization
  - The resource is acquired in a constructor
- Resource relinquishing
  - Happens in the destructor
    - Close the file
    - Deallocate the memory
    - Release the lock

Unique Pointers

Smart Pointers

`unique_ptr`

- Simple smart pointer – very efficient!

- `unique_ptr<T>`
  - Points to an object of type T on the heap
  - It is unique – there can only be one `unique_ptr<T>` pointing to the object on the heap
  - Owns what it points to
  - Cannot be assigned or copied
  - CAN be moved
  - When the pointer is destroyed, what it points to is automatically destroyed

Smart Pointers

`unique_ptr` – creating, initializing and using

```
{
    std::unique_ptr<int> p1 {new int {100} };

    std::cout << *p1 << std::endl;     // 100

    *p1 = 200;

    std::cout << *p1 << std::endl;     // 200

}// automatically deleted
```

Smart Pointers

`unique_ptr` – some other useful methods

```
{
    std::unique_ptr<int> p1 {new int {100} };

    std::cout << p1.get() << std::endl;   // 0x564388

    p1.reset(); // p1 is now nullptr

    if (p1)
      std::cout << *p1 << std::endl;      // won't execute
}// automatically deleted
```

Smart Pointers

`unique_ptr` – user defined classes

```
{
    std::unique_ptr<Account> p1 {new Account{"Larry"}};
    std::cout << *p1 << std::endl;  // display account

    p1->deposit(1000);
    p1->withdraw(500);


}// automatically deleted
```

Smart Pointers

`unique_ptr` – vectors and move

```
    {
        std::vector<std::unique_ptr<int>> vec;

        std::unique_ptr<int> ptr {new int{100}};

        vec.push_back(ptr);   // Error – copy not allowed

        vec.push_back(std::move(ptr));

    }// automatically deleted
```

Smart Pointers

`unique_ptr` – make_unique (C++14)

```
{
    std::unique_ptr<int> p1 = make_unique<int>(100);

    std::unique_ptr<Account> p2  = make_unique<Account>("Curly", 5000);

    auto p3 = make_unique<Player>("Hero", 100, 100);

}// automatically deleted
```

More efficient – no calls to `new` or `delete`

Shared Pointers

Smart Pointers

`shared_ptr`

- Provides shared ownership of heap objects

- `shared_ptr<T>`
  - Points to an object of type T on the heap
  - It is not unique – there can many `shared_ptr`s pointing to the same object on the heap
  - Establishes shared ownership relationship
  - CAN be assigned and copied
  - CAN be moved
  - Doesn't support managing arrays by default
  - When the use count is zero, the managed object on the heap is destroyed

Smart Pointers

`shared_ptr` – creating, initializing and using

```
{
    std::shared_ptr<int> p1 {new int {100} };

    std::cout << *p1 << std::endl;     // 100

    *p1 = 200;

    std::cout << *p1 << std::endl;     // 200

}// automatically deleted
```

Smart Pointers

`shared_ptr` – some other useful methods

```
{
    // use_count - the number of shared_ptr objects managing the heap object
    std::shared_ptr<int> p1 {new int {100} };
    std::cout << p1.use_count () << std::endl;          // 1

    std::shared_ptr<int> p2 { p1 };                     // shared ownership
    std::cout << p1.use_count () << std::endl;          // 2

    p1.reset();       // decrement the use_count; p1 is nulled out
    std::cout << p1.use_count() << std::endl;           // 0
    std::cout << p2.use_count() << std::endl;           // 1
}  // automatically deleted
```

Smart Pointers

`shared_ptr` – user defined classes

```
{
    std::shared_ptr<Account> p1 {new Account{"Larry"}};
    std::cout << *p1 << std::endl;  // display account

    p1->deposit(1000);
    p1->withdraw(500);

}// automatically deleted
```

Smart Pointers

`shared_ptr` – vectors and move

```
{
    std::vector<std::shared_ptr<int>> vec;

    std::shared_ptr<int> ptr {new int{100}};

    vec.push_back(ptr);   // OK - copy IS allowed

    std:: cout << ptr.use_count() << std::endl;     // 2
}// automatically deleted
```

Smart Pointers

`shared_ptr – make_shared` (C++11)

```
{
    std::shared_ptr<int> p1 = std::make_shared<int>(100); // use_count: 1
    std::shared_ptr<int> p2 { p1 };                       // use_count : 2
    std::shared_ptr<int> p3;
    p3 = p1;                                              // use_count : 3

}// automatically deleted
```

- Use `std::make_shared` – it's more efficient!
- All 3 pointers point to the SAME object on the heap!
- When the use_count becomes 0 the heap object is deallocated

Weak Pointers

Smart Pointers

`weak_ptr`

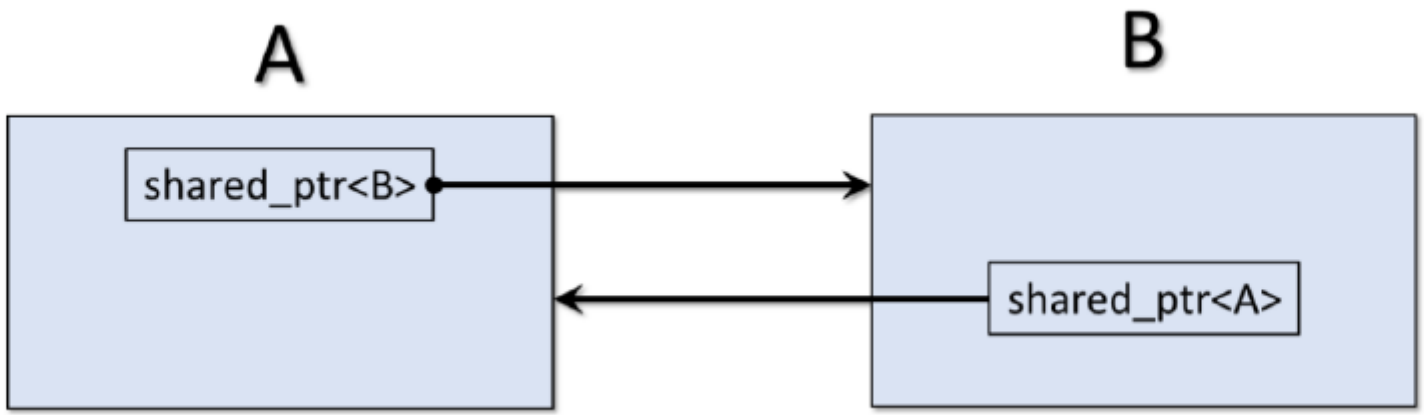
- Provides a non-owning “weak” reference

- `weak_ptr<T>`
  - Points to an object of type T on the heap
  - Does not participate in owning relationship
  - Always created from a `shared_ptr`
  - Does NOT increment or decrement reference use count
  - Used to prevent strong reference cycles which could prevent objects from being deleted

Smart Pointers

`weak_ptr` – circular or cyclic reference

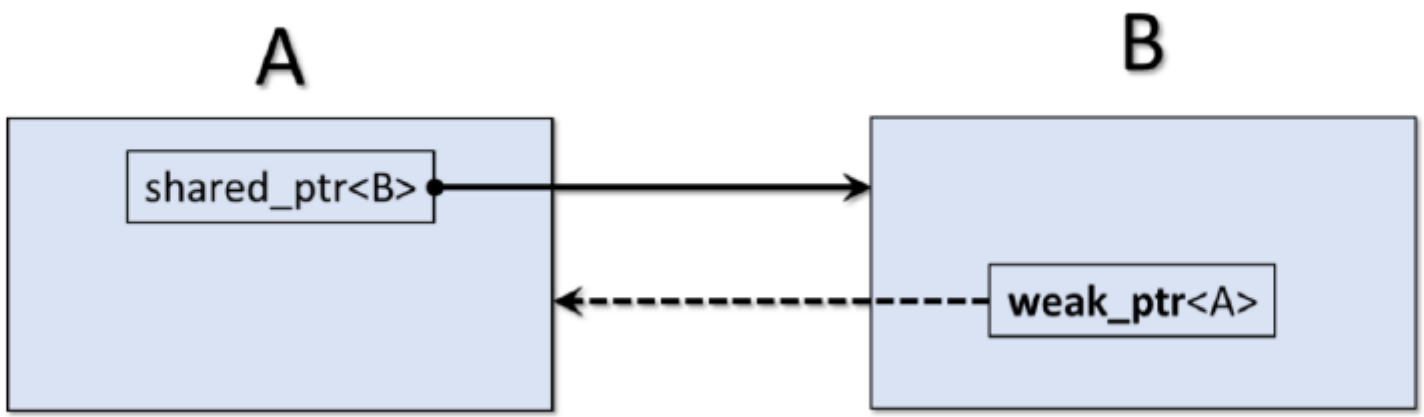
- A refers to B
- B refers to A
- Shared strong ownership prevents heap deallocation



Smart Pointers

`weak_ptr` – circular or cyclic reference

- Solution – make one of the pointers non-owning or 'weak'
- Now heap storage is deallocated properly



Custom deleters

Smart Pointers

Custom deleters

- Sometimes when we destroy a smart pointer we need more than to just destroy the object on the heap
- These are special use-cases
- C++ smart pointers allow you to provide custom deleters
- Lots of way to achieve this
  - Functions
  - Lambdas
  - Others. . .

Smart Pointers

Custom deleters - function

```
void my_deleter(Some_Class *raw_pointer) {
    // your custom deleter code
    delete raw_pointer;
}


shared_ptr<Some_Class> ptr { new Some_class{}, my_deleter };
```

Smart Pointers

Custom deleters - function

```
void my_deleter(Test *ptr) {
    cout << "In my custom deleter" << end;
    delete ptr;
}


shared_ptr<Test> ptr { new Test{}, my_deleter };
```

Smart Pointers

Custom deleters - lambda

```
shared_ptr<Test> ptr (new Test{100}, [] (Test *ptr)  {
        cout << "\tUsing my custom deleter" << endl;
        delete ptr;
});
```

Good Luck!