

COMP110: Principles of Computing

Smart Pointers

Statics and singletons

Static members

- ▶ Class members (methods and fields) can be marked as **static**
- ▶ They are then **shared** across **all instances** of the class
- ▶ Static members can be accessed from **outside** the class using `::` notation

The singleton pattern

- ▶ A **singleton** class has a **single static instance**
- ▶ A **static** `getInstance` function returns a **reference** to the instance
- ▶ There is **one and only one** instance — creating new instances is not allowed, neither is destroying the existing instance

In TextureManager.h

```
class TextureManager
{
public:
    static TextureManager& getInstance()
    { return instance; }

    Texture* getTexture(const std::string& name);

private:
    TextureManager() { };
    static TextureManager instance;
};
```

In TextureManager.cpp

```
#include "TextureManager.h"

TextureManager TextureManager::instance;
```

Key points:

- ▶ Constructor is **private** to prevent creation of extra instances
- ▶ `instance` and `getInstance` are **static**, everything else is **not static**
- ▶ Static variables must be **instantiated** in a `.cpp` file
 - ▶ Optionally with constructor parameters

Example usage:

```
Texture* texture = TextureManager::getInstance(). ←  
    getTexture("player.png");
```

Statics and initialisation

- ▶ Static members are initialised at the **very start of the program**
 - ▶ I.e. **before** `main()` is entered
- ▶ The order of initialisation is **undefined**
 - ▶ **Do not** make your static initialisation code rely on other statics having been initialised already — this **will** cause obscure bugs!
- ▶ Further reading: <https://isocpp.org/wiki/faq/ctors#static-init-order>
- ▶ Consider using the **construct on first use** idiom if your singleton class has a complex constructor

Smart pointers

Motivation

- ▶ Pointers in C++ are powerful, but with great power comes great responsibility!
- ▶ In particular, responsibility for the **lifetime** of object instances, i.e. remembering to call `delete` at the right time
- ▶ C++11 introduced **smart pointers** to try and make this easier

Unique pointer

- ▶ Defined in standard header file `<memory>`
- ▶ `std::unique_ptr` has **sole ownership** of the instance to which it points
- ▶ I.e. two `unique_ptr`s **cannot** point to the same instance
- ▶ Use `std::make_unique<T>` instead of `new T`
- ▶ The instance is destroyed when the `unique_ptr` goes **out of scope**, or when it is assigned to point to a different instance

Unique pointer example

```
#include "stdafx.h" // --> #include <memory>

class MyClass { };

int main()
{
    std::unique_ptr<MyClass> p
        = std::make_unique<MyClass>();
    return 0;
    // p is automatically deleted here
}
```

Aside: automatic type inference

- ▶ When declaring a **local variable** with an initial value, can use `auto` in place of the type
- ▶ The compiler **infers** the type from the type of the initial value

```
// The following are equivalent:  
std::unique_ptr<Duck> duck = std::make_unique<Duck>();  
auto duck = std::make_unique<Duck>();
```

- ▶ Careful — this can make your code **more readable** or **less readable** depending on how and where you use it!

Vectors of objects revisited

From last time:

- ▶ `std::vector<Duck>`: when the vector changes size, instances are **copied** and the old ones **destroyed**
- ▶ `std::vector<Duck*>`: no copying and destroying, but you must remember to **delete** elements on removal

But now:

- ▶ `std::vector<std::unique_ptr<Duck>>`: class instances stay put, but are automatically destroyed when removed from the `vector`!

Unique pointers can't be copied

```
auto p = std::make_unique<MyClass>();  
auto q = p;
```

- This won't compile!

 C2280 'std::unique_ptr<MyClass,std::default_delete<_Ty>>::unique_ptr(const std::unique_ptr<_Ty,std::default_delete<_Ty>> &)' : attempting to reference a deleted function

- Translation: assigning one `unique_ptr` from another is forbidden

Aside: default and deleted functions

- ▶ As standard, C++ classes come with constructors and methods for **copying** and **moving** instances
- ▶ You (the class developer) can **override** these methods, make them **protected** or **private**, or **delete** them entirely (e.g. to forbid copying)
- ▶ Further reading:
 - ▶ `http://www.stroustrup.com/C++11FAQ.html#default`
 - ▶ `http://en.cppreference.com/w/cpp/language/classes`

Unique pointers can be moved

```
auto p = std::make_unique<MyClass>();  
auto q = std::move(p);
```

- ▶ Now `q` has **ownership** of the instance
- ▶ `p` no longer refers to this instance
- ▶ In fact `p` becomes null
- ▶ Another way you are allowed to move `unique_ptr`s is by **swapping**:

```
auto p = std::make_unique<MyClass>("hello");  
auto q = std::make_unique<MyClass>("world");  
std::swap(p, q);
```


Shared pointers

- ▶ Unique pointers have their uses, but uniqueness is a big restriction
- ▶ C++ also has `std::shared_ptr`, which does allow multiple pointers to the same instance
- ▶ **Reference counting** ensures the instance is destroyed when **all** `shared_ptr`s to it have gone away (and not before!)

```
int main()
{
    bool flag = true;
    std::shared_ptr<MyClass> p = nullptr;

    if (flag)
    {
        auto q = std::make_shared<MyClass>();
        p = q;
    }
    /* q is out of scope, but p still holds a ↵
       reference to the instance so it stays alive */

    if (p)
        p->doSomething();

    return 0;
    /* p is out of scope now, so the instance is ↵
       destroyed */
}
```

Reference counting

- ▶ Objects managed by `shared_ptr` have a **reference count**, initially 0
- ▶ When a `shared_ptr` is made to point to the instance, its reference count is **incremented**
- ▶ When a `shared_ptr` no longer points to the instance (because it goes out of scope or is reassigned), the reference count is **decremented**
- ▶ When the reference count is decremented to 0, the instance is destroyed

Smart pointers and composition

- ▶ We have seen `unique_ptr` and `shared_ptr` used as **local variables**
- ▶ They can also be used as **fields** within classes
- ▶ When the instance containing them is destroyed:
 - ▶ `unique_ptr` destroys the instance to which it points
 - ▶ `shared_ptr` decrements the reference count on the instance to which it points, which may result in it being destroyed
- ▶ ... just as you would expect (hopefully)!

```
class Duck
{
public:
    Duck(const std::shared_ptr<Pond>& pond)
        : pond(pond),
          bill(std::make_unique<Bill>())
    { }

private:
    std::unique_ptr<Bill> bill;
    std::shared_ptr<Pond> pond;
};
```

When a `Duck` instance is destroyed:

- ▶ Its `Bill` is also destroyed;
- ▶ Its `Pond` is destroyed **if and only if** there are no other `shared_ptr`s to it (e.g. in other `Duck` instances)

```
class Bar;

class Foo
{
public:
    std::shared_ptr<Bar> bar;
};

class Bar
{
public:
    std::shared_ptr<Foo> foo;
};

int main()
{
    auto p = std::make_shared<Foo>();
    p->bar = std::make_shared<Bar>();
    p->bar->foo = p;
}
```

Reference cycles

- ▶ In the example on the previous slide, the instances are **not** destroyed properly at the end of `main()`
- ▶ `Foo` still holds a reference to `Bar`, but `Bar` holds a reference to `Foo`
- ▶ This prevents both objects' reference counts from reaching 0
- ▶ Solution: make one of the references a **weak pointer**

Weak pointers

- ▶ `std::weak_ptr` is similar to `std::shared_ptr`, except it does **not** alter the reference count of the instance
- ▶ A `weak_ptr` must be **locked** in order to access the instance to which it points

```
std::shared_ptr<MyClass> lockedInstance  
    = weakPtr.lock();
```

- ▶ Locking creates a temporary `shared_ptr` to the instance — this ensures that the reference count stays above 0 while the instance is being used

Smart pointers — Summary

- ▶ `std::shared_ptr` uses **reference counting** to manage the lifetime of objects
- ▶ `std::weak_ptr` is useful for breaking **reference cycles** when using `shared_ptr`s for composition
- ▶ `std::unique_ptr` can be used when you want to enforce that there is **only one** pointer to a particular instance
- ▶ NB: all smart pointer types allow **polymorphism**, e.g.

```
class Bird {};  
class Duck : public Bird {};  
  
std::shared_ptr<Bird> bird = std::make_unique<Duck>();
```

What about “dumb” pointers?

- ▶ In modern C++, it is **almost always preferable** to use smart pointers instead of normal C++ pointers
- ▶ I.e. use `std::shared_ptr<T>` instead of `T*`, and `std::make_shared` instead of `new`, and then you never have to worry about calling `delete`
- ▶ So why did we bother teaching you about normal C++ pointers?!
 - ▶ Because C++ code written before 2011 (and much code written after) uses them extensively
 - ▶ Because sometimes you need to use them, e.g. when working with SDL or other APIs / libraries
 - ▶ Because once you can write a nontrivial program that uses pointers and doesn't crash or leak memory, you can call yourself a Real Programmer ☺

Reminders

This Wednesday (9th March)

Your proposal for **COMP110 Coding Task 2** is due **in the lecture**

- ▶ Bring it with you for us to check in class

Your A* pathfinding program for **COMP110 Worksheet 5** is due **by 6pm**

- ▶ Submit a pull request on GitHub
- ▶ Book a tutor meeting to discuss and sign off

Wednesday's lecture is a **COMP140** lecture

- ▶ Heuristic analysis of your game controllers