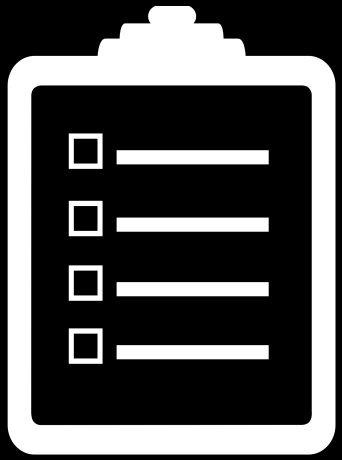
RAII and Smart Pointers

Ali Malik
malikali@stanford.edu

Game Plan



Recap

Conversion Operators

RAII

Smart Pointers

Recap

Initialisation vs Assignment

Initialisation:

Transforms an object's initial junk data into valid data.

Assignment:

Replaces existing valid data with other valid data.

Constructors

Normal Constructor:

- What you are used to!

Copy Constructor

- Initialise an instance of a type to be a copy of another instance

Copy Assignment

- Not a constructor
- Assign an instance of a type to be a copy of another instance

The Rule of Three

If you implement a copy constructor, assignment operator, or destructor, you should implement the others, as well

Conversion Operators

Conversion Operators

Let you define how a class can be converted to other types.

For example, we could define a conversion of the `MyVector` to a `bool` to be false if the vector is empty and true otherwise.

Conversion Operators

Converting to `Type` works by overloading the `Type()` operator.

Doesn’t have a return value.

```
class MyClass {

public:
    operator Type() {
        // return something of type Type
    }
}
```

Conversion Operators

An example defining a `bool` conversion for `MyVector` :

```
class MyVector {
public:
    operator bool() {
        return empty();
    }
};

MyVector v;
if(v) {
    cout << v[0] << endl;
}
```

RAII

Resource

Let’s first talk about the abstraction of a resource.

We will look at file opening and closing in C as a case study.

C File I/O

To read a file in C, you need to:

1. Open the file with `fopen`
2. Read data using `fgets`
3. Close the open file with `fclose`

If a programmer doesn't remember to close an open file, bad things happen (memory leaks, crashes etc.)

C File I/O

You can think of this as a resource.

What is a resource?

- Anything that exists in limited supply.
- Something you have to acquire and release.

Examples: memory, open files, sockets etc.

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C File I/O

To read a file in C, you need to:

1. Open the file with `fopen` `// acquire`
2. Read data using `fgets`
3. Close the open file with `fclose` `// release`

If a programmer doesn't remember to close an open file, bad things happen (memory leaks, crashes etc.)

Resources

Other examples of resources:

	Acquire	Release
Files	`fopen`	`fclose`
Memory	`new, new[]`	`delete, delete[]`
Locks	`lock, try_lock`	`unlock`
Sockets	`socket`	`close`

RAII

Resource Acquisition Is Initialisation

RAII

A modern C++ idiom.

When you initialize an object, it should already have acquired any resources it needs (in the constructor).

When an object goes out of scope, it should release every resource it is using (using the destructor).

RAII

Key points:

- There should never be a half-ready or half-dead object.
- When an object is created, it should be in a ready state.
- When an object goes out of scope, it should release its resources.

RAII

Key points:

- There should never be a half-ready or half-dead object.
- When an object is created, it should be in a ready state.
- When an object goes out of scope, it should release its resources.

The user shouldn’t have to do anything more.

C File I/O

How does C File I/O violate RAII?

```
void printFile(const char* name) {
    // acquire file resource
    FILE* f = fopen(name, "r");

    // print contents of f

    // release file resource
    fclose(f);
}
```

C File I/O

How does C File I/O violate RAII?

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C File I/O

How does C File I/O violate RAII?

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void printFile(const char* name) {
    // acquire file resource
    FILE* f = fopen(name, "r");

    // print contents of f

    // release file resource?

}
```

C File I/O

How does C File I/O violate RAII?

```
void printFile(const char* name) {
    // acquire file resource
    FILE* f = fopen(name, "r");

    // print contents of f

    // release file resource?

}
```

`f` goes out of scope, but doesn't release its resources.

C File I/O

What would be an RAII friendly solution for C File I/O?

C File I/O + RAII

```
class FileObj {
public:
    FILE* ptr;
    FileObj(char* name)
        : ptr(fopen(name, "r") {}

    ~FileObj() {
        fclose(ptr);
    }
};
```

C File I/O

Our new printFile method would look like:

```
void printFile(const char* name) {
    // initialization will acquire resources
    FileObj fobj(name);

    // print contents of f

    // FileObj destructor will release resources
}
```

C File I/O

In fact, you have already been using RAII!

For example:

- You can create an ifstream and it will open the file
- When the ifstream goes out of scope, its destructor closes the file.

Don’t actually need to call the `.close()` method.

RAII - An Aside

RAII is a bad name for the concept.

"The best example of why I shouldn't be in marketing"

"I didn't have a good day when I named that"

Bjarne Stroustrup, still unhappy with the name RAII in 2012

RAII - An Aside

A better name is probably:

Constructor Acquires, Destructor Releases

or

Scope Based Resource Management

Smart Pointers

Smart Pointers

What is another thing that violates RAII?

Raw Pointers and heap allocation!

Smart Pointers

Calls to `new` acquire resource (memory).

Calls to `delete` release resource.

But this is not automatically done when the pointers go out of scope.

Smart Pointers

But this is not automatically done when the pointers go out of scope:

```
void rawPtrFn() {
    // acquire memory resource
    Node* n = new Node;

    // manually release memory
    delete n;
}
```

Smart Pointers

But this is not automatically done when the pointers go out of scope:

```
void rawPtrFn() {
    // acquire memory resource
    Node* n = new Node;

    // manually release memory
    delete n;
}
```

If we forget this, we leak memory.

Smart Pointers

What would be an RAII solution to this?

Have a class that

- Allocates the memory when initialized
- Frees the memory when destructor is called
- Allows access to underlying pointer

Smart Pointers

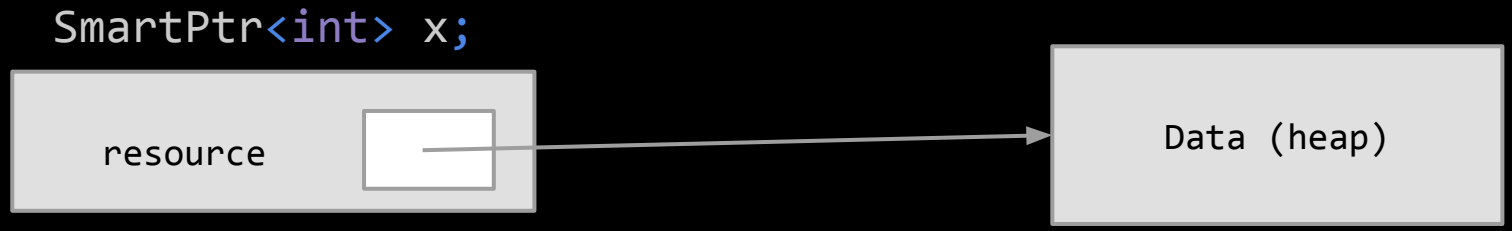
Let’s plan and write this up:

`Smart Pointers`

`(RAIIPtr_unique.pro)`

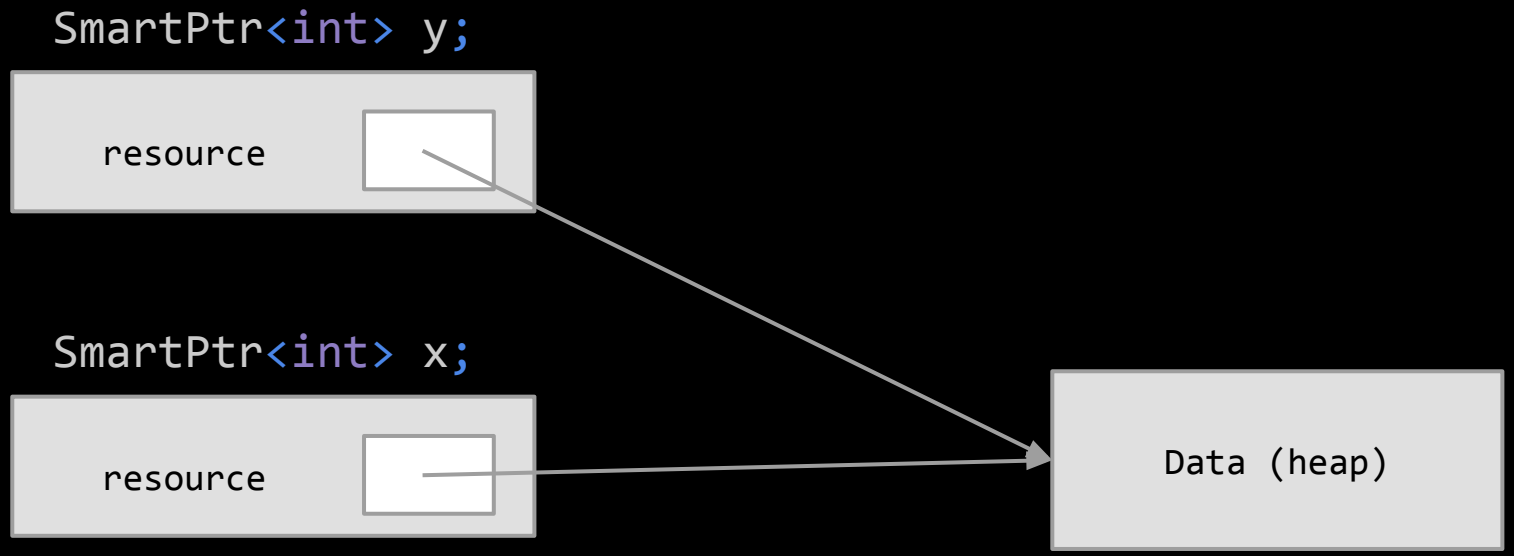
Smart Pointers

First we make a smart pointer



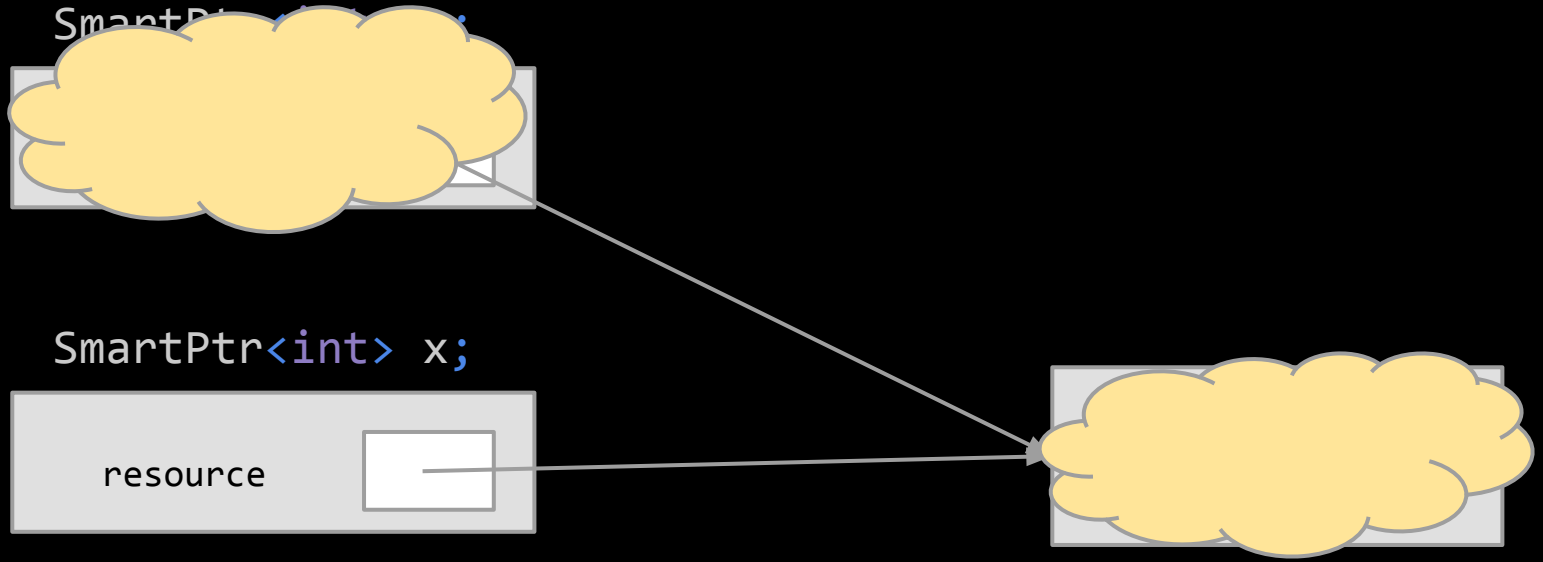
Smart Pointers

We then make a copy of our smart pointer



Smart Pointers

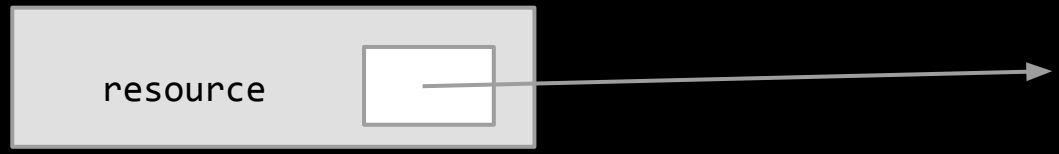
When y goes out of scope, it deletes the heap data



Smart Pointers

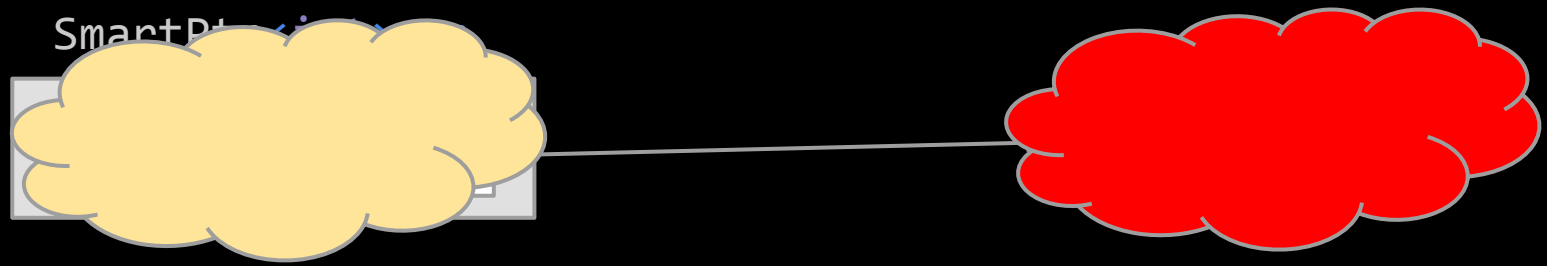
This leaves x pointing at deallocated data

```
SmartPtr<int> x;
```



Smart Pointers

If we dereference x or its destructor calls delete, we crash



Smart Pointers

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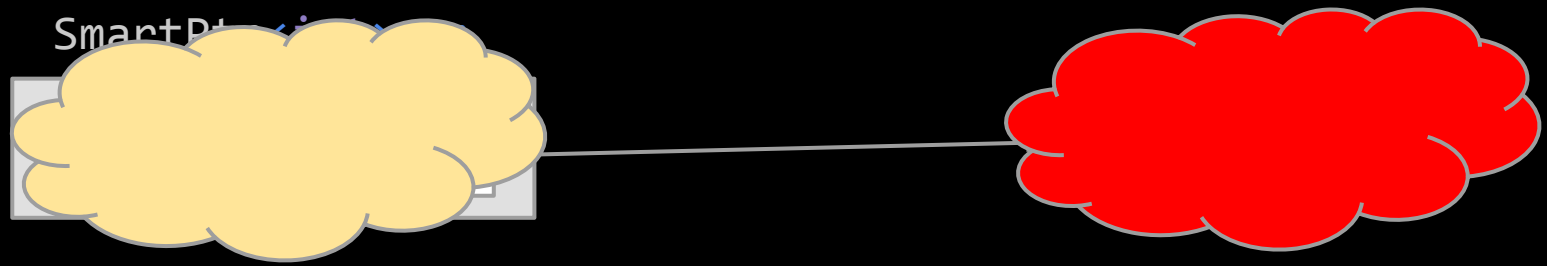

Smart Pointers

Have to be careful when copying an RAII object

Don’t want two objects thinking they both exclusively own a resource

Smart Pointers

C++ already has built-in smart pointers.

- `std::unique_ptr`
- `std::shared_ptr`
- `std::weak_ptr`

unique_ptr

Similar to what we wrote earlier

Uniquely own its resource and deletes it when the object is destroyed

Cannot be copied!

```
{
    std::unique_ptr<int> p(new int);
    // Use p
}
// Freed!
```

shared_ptr

Resource can be stored by any number of shared_ptrs

Deleted when none of them point to it

```
{
    std::shared_ptr<int> p1(new int);
    // Use p1
    {
        std::shared_ptr<int> p2 = p1;
        // Use p1 and p2
    }
    // Use p1
}
// Freed!
```

shared_ptr

How are these implemented?

Reference counting!

Store an int that keeps track of the number currently referencing that data

- Gets incremented in copy constructor/copy assignment
- Gets decremented in destructor or when overwritten with copy assignment

Frees the resource when reference count hits 0

Smart Pointers

See Course Reader pg. 351 onwards for details. Let's plan and write this up:

`Smart Pointers`
`(RAIIPtr_shared.pro)`

weak_ptr

Used to deal with circular references of shared_ptr

Read documentation to learn more!

Next Time

Final Topics