Smart Pointers

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COE 322 Fall 2020



Recursive data structures

```
class Node {
private:
  int value;
  Node tail;
  /* ... */
};
This does not work: would take infinite memory.
class Node {
private:
  int value;
  PointToNode tail;
  /* ... */
};
```

PointToNode 'points' to the first node of the tail.



Pointer types

- Smart pointers. You will see 'shared pointers'.
- There are 'unique pointers'. Those are tricky.
- Please don't use old-style C pointers.
- Unless you become very advanced.



Simple example

Simple class that stores one number:

```
class HasX {
private:
   double x;
public:
   HasX( double x) : x(x) {};
   auto get() { return x; };
   void set(double xx) { x = xx; };
};
```



Creating a shared pointer

Allocation and pointer in one:

```
shared_ptr<Obj> X =
    make_shared<Obj>( /* constructor args */ );
  // or:
auto X = make_shared<Obj>( /* args */ );
Code:
                                            Output
                                            [pointer] pointx:
HasX xobj(5);
cout << xobj.get() << endl;</pre>
                                            5
xobj.set(6);
cout << xobj.get() << endl;</pre>
auto xptr = make_shared<HasX>(5);
cout << xptr->get() << endl;</pre>
xptr->set(6);
cout << xptr->get() << endl;</pre>
```



Headers for smart pointers

Using shared pointers requires at the top of your file:

```
#include <memory>
using std::shared_ptr;
using std::make_shared;
```



What's the point of pointers?

Pointers make it possible for two variables to own the same object.

Code:

```
auto xptr = make_shared<HasX>(5);
auto yptr = xptr;
cout << xptr->get() << endl;
yptr->set(6);
cout << xptr->get() << endl;</pre>
```

Output [pointer] twopoint:

5 6



Automatic memory management



Memory leaks

C has a 'memory leak' problem

```
// the variable 'array' doesn't exist
{
    // attach memory to 'array':
    double *array = new double[N];
    // do something with array
}
// the variable 'array' does not exist anymore
// but the memory is still reserved.
```

The application 'is leaking memory'.

Java/Python have 'garbage collection': runtime impact

C++ has the best solution: smart pointers.



Reference counting illustrated

We need a class with constructor and destructor tracing:

```
class thing {
public:
   thing() { cout << ".. calling constructor\n"; };
   ~thing() { cout << ".. calling destructor\n"; };
};</pre>
```



Pointer overwrite

Let's create a pointer and overwrite it:

Code:

Output [pointer] ptr1:

```
set pointer1
.. calling constructor
overwrite pointer
.. calling destructor
```



Pointer copy

Code:

Output [pointer] ptr2:

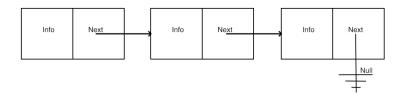
```
set pointer2
.. calling constructor
set pointer3 by copy
overwrite pointer2
overwrite pointer3
.. calling destructor
```



Example: linked lists



Linked list





Linked lists

The prototypical example use of pointers is in linked lists. Consider a class Node with

- a data value to store, and
- a pointer to another Node, or nullptr if none.

Constructor sets the data value: Set next / test if there is a next:

```
class Node {
private:
    int datavalue{0};
    shared_ptr<Node>
        tail_ptr{nullptr};
public:
    Node() {}
    Node(int value)
    : datavalue(value) {};
    int value() { return
        datavalue; };
}
bool has_next() {
    return tail_ptr!=nullptr; };

return tail_ptr!=nullptr; };

public:
    Node() {}
    Node(int value)
    idatavalue() {};
    int value() { return
        datavalue; };
}
```



List usage



first->print();

Linked lists and recursion

Many operations on linked lists can be done recursively:

```
int Node::list_length() {
  if (!has_next()) return 1;
  else return 1+tail_ptr->list_length();
};
```



Exercise 1

Write a method set_tail that sets the tail of a node.

```
Node one;
one.set_tail( two ); // what is the type of 'two'?
cout << one.list_length() << endl; // prints 2</pre>
```



Exercise 2

Write a recursive append method that appends a node to the end of a list:

Code:

```
auto
  first = make_shared<Node>(23),
  second = make_shared<Node>(45)
```

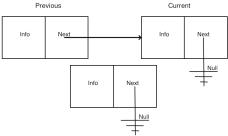
```
second = make_shared<Node>(45),
  third = make_shared<Node>(32);
first->append(second);
first->append(third);
first->print();
```

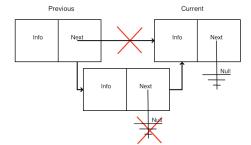
Output [tree] append:

```
Append 23 & 45 gives <<23,45>>
Append 32 gives <<23,45,32>>
```











Exercise 3

Write a recursive *insert* method that inserts a node in a list, such that the list stays sorted:

Code:

```
auto
  first = make_shared<Node>(23),
  second = make_shared<Node>(45),
  third = make_shared<Node>(32);
first->insert(second);
first->insert(third);
first->print();
```

Output [tree] insert:

```
Insert 45 on 23 gives <<23,45>>
Insert 32 gives <<23,32,45>>
```

Assume that the new node always comes somewhere after the head node.

