Smart Pointers

Victor Eijkhout, Susan Lindsey

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Recursive data structures

```
clast Node {
private:
  int value;
  Node tail;
  /* ... */
};
```

This does not work: would take infinite memory.

```
clast Node {
private:
  int value;
  PointToNode tail;
  /* ... */
};
```

Pointer 'points' to the location 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.

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 */ );

X->method_or_member;
```

Simple example

Code:

```
class HasX {
private:
  double x;
public:
  HasX( double x) : x(x) {};
  auto &val() { return x; };
};

int main() {
  auto X = make_shared<HasX>(5);
  cout << X->val() << endl;
  X->val() = 6;
  cout << X->val() << endl;
```

Output
[pointer] pointx:

```
5
6
```

Headers for smart pointers

Using shared pointers requires at the top of your file:

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

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"; };
};
```

Pointer overwrite

Let's create a pointer and overwrite it:

Code:

```
cout << "set pointer1"
     << endl;
auto thing_ptr1 =
  make_shared<thing>();
cout << "overwrite pointer"
     << endl;
thing_ptr1 = nullptr;
```

Output
[pointer] ptr1:

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

Pointer copy

Code:

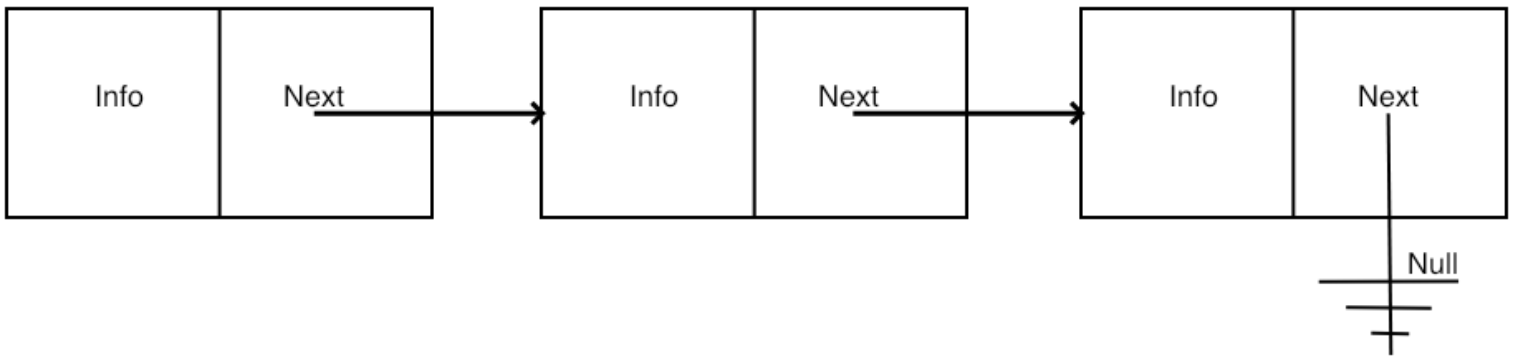
```
cout << "set pointer2" << endl;
auto thing_ptr2 =
  make_shared<thing>();
cout << "set pointer3 by copy"
     << endl;
auto thing_ptr3 = thing_ptr2;
cout << "overwrite pointer2"
     << endl;
thing_ptr2 = nullptr;
cout << "overwrite pointer3"
     << endl;
thing_ptr3 = nullptr;
```

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. Let a class *Node* be given:

```
class Node {
private:
  int datavalue{0};
  shared_ptr<Node> tail_ptr{
    nullptr};
public:
  Node() {}
  Node(int value) { datavalue =
     value; };
  void set_tail( shared_ptr<
    Node> tail ) {
    tail_ptr = tail; };
```

```
void print() {
  cout << datavalue;
  if (has_next()) {
    cout << ", "; tail_ptr->
    print();
  }
};
```

List usage

Example use:

Code:

```
auto
  first = make_shared<Node>(23),
  second = make_shared<Node>(45);
first->set_tail(second);
cout << "List length: "
     << first->list_length() << endl;
first->print();
```

Output
[tree] simple:

```
List <<23,45>> has length 2
```

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

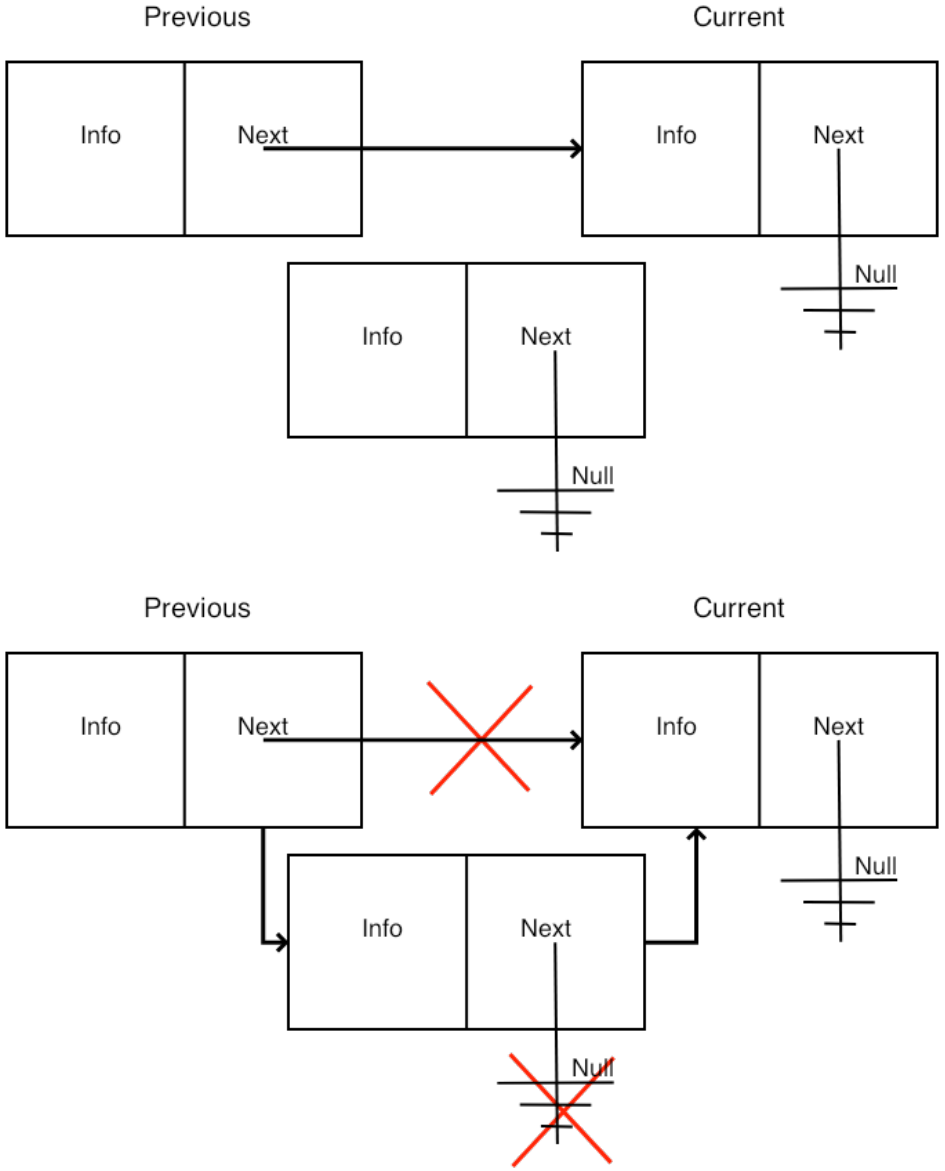
Code:

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

Insertion


Previous
Current
Info
Next
Info
Next
Null
Info
Next
Null
Previous
Current
Info
Next
Info
Next
Null
Info
Next
Null

Exercise 2

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>>
```