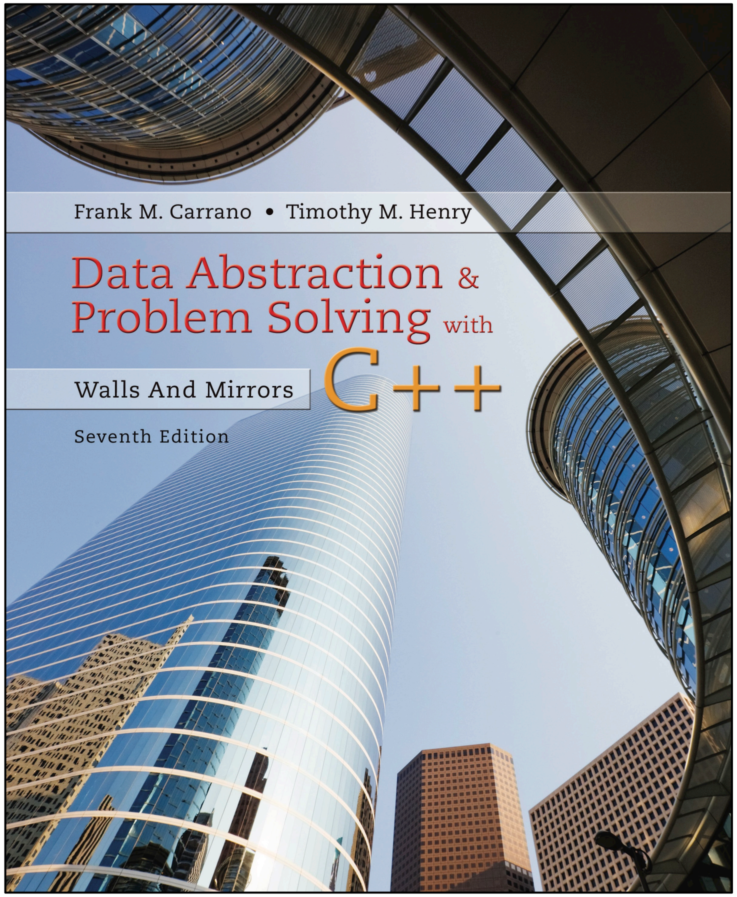
# Data Abstraction & Problem Solving with C++: Walls and Mirrors

Seventh Edition




## C++ Interlude 4

Safe Memory Management Using Smart Pointers

# Raw Pointers (1 of 3)

- Allocate memory in free store by using **new** operator
  - Returns reference to newly created object in memory
- Store reference to object in a pointer variable
  - Use pointer variable to access object
- Copy reference to another pointer variable
  - Creates alias to same object

# Raw Pointers (2 of 3)

- Use **delete** operator to deallocate object's memory
  - Must also set to **nullptr** any pointer variables that referenced the object
- Need to keep track number of aliases that reference an object … else results in
  - Dangling pointers
  - Memory leaks
  - Other errors (program crash, wasted memory, …)

# Raw Pointers (3 of 3)

- Languages such as Java and Python disallow direct reference to objects
  - Use reference counting to track number of aliases that reference an object
  - Known as the “reference count”
- Language can detect when object no longer has references
  - Can deallocate … known as “garbage collection”

# Smart Pointers (1 of 2)

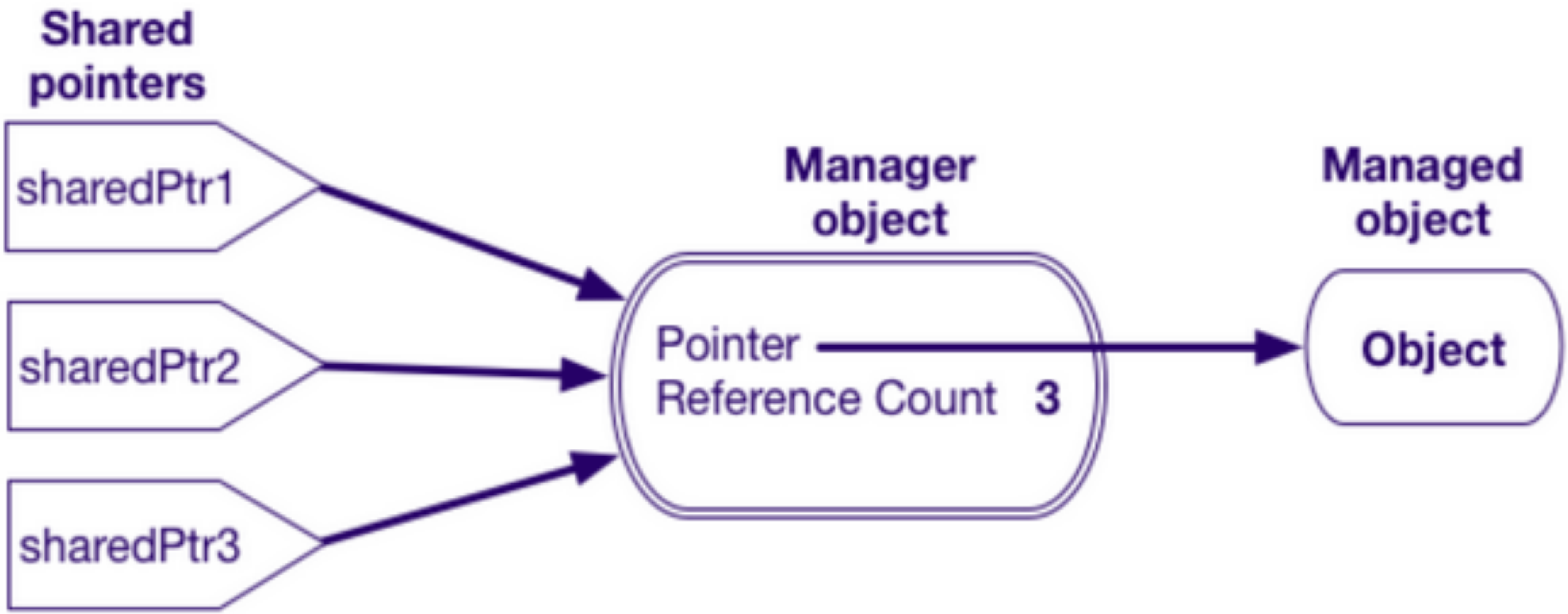
- C++ now supports “smart” pointers (or managed pointers)
  - Act like raw pointers
  - Also provide automatic memory management features
- When you declare a smart pointer
  - Placed on application stack
  - Smart pointer references an object ⇨ object is “managed”

# Smart Pointers (2 of 2)

- Smart-pointer templates
  - **shared_ptr** – provides shared ownership of object
  - **unique_ptr** – no other pointer can reference same object
  - **weak_ptr** – reference to an object already managed by a shared pointer … does not have ownership of the object

# Using Shared Pointers (1 of 2)

**Figure C4-1** Shared pointers and the manager object referencing a managed object.



# Using Shared Pointers (2 of 2)

- A shared pointer …
  - Provides a safe mechanism to implement shared object ownership
  - Maintains a count of aliases to an object
  - Decreases or increases reference count of managed object each time instance is created or goes out of scope or is assigned **nullptr**
  - Calls destructor of managed object when reference count reaches 0

# Revised Node and LinkedList Classes (1 of 11)

- Use shared pointers in earlier Node and LinkedList classes
  - Help ensure memory handled correctly

**Listing C4-1** The revised header file for the class **Node**, originally given in Listing 4-1

```
#include <memory>
template<class ItemType>
class Node
{
private:
   ItemType item;                           // A data item
   std::shared_ptr<Node<ItemType>> next; // Pointer to next node
```

# Revised Node and LinkedList Classes (2 of 11)

## Listing C4-1 [Continued]

```
public:
   Node();
   Node(const ItemType& anItem);
   Node(const ItemType& anItem,
           std::shared_ptr<Node<ItemType>> nextNodePtr);
   void setItem(const ItemType& anItem);
   void setNext(std::shared_ptr<Node<ItemType>> nextNodePtr);
   ItemType getItem() const ;
   auto getNext() const ;
}; // end Node
```

# Revised Node and LinkedList Classes 

**Listing C4-2** The revised implementation file for the class **Node**, originally given in Listing 4- 2

```
#include "Node.h"

template<class ItemType>
Node<ItemType>::Node()
{ } // end default constructor

template<class ItemType>
Node<ItemType>::Node(const ItemType& anItem)
                  : item(anItem)
{ } // end constructor

template<class ItemType>
Node<ItemType>::Node(const ItemType& anItem,
                     std::shared_ptr<xNode<ItemType>> nextNodePtr)
                  : item(anItem), next(nextNodePtr)
{ } // end constructor
```

# Revised Node and LinkedList Classes 

**Listing C4-2 [Continued]**

```
template<class ItemType>
void Node<ItemType>::setItem(const ItemType& anItem)
{
   item = anItem;
} // end setItem

template<class ItemType>
void Node<ItemType>::setNext(std::shared_ptr<Node<ItemType>> nextNodePtr)
{
   next = nextNodePtr;
} // end setNext

template<class ItemType>
ItemType Node<ItemType>::getItem() const
{
   return item;
} // end getItem
```

# Revised Node and LinkedList Classes (5 of 11)

**Listing C4-2 [Continued]**

```
} // end getItem

template<class ItemType>
auto Node<ItemType>::getNext() const
{
   return next;
} // end getNext
```

# Revised Node and LinkedList Classes (6 of 11)

**Listing C4-3** The insert method for **LinkedList**

```
template<class ItemType>
bool LinkedList<ItemType>::insert(int newPosition,
                                  const ItemType& newEntry)
{
   bool ableToInsert = (newPosition >= 1) &&
                       (newPosition <= itemCount + 1);
   if (ableToInsert)
   {
      // Create a new node containing the new entry
      auto newNodePtr = std::make_shared<Node<ItemType>>(newEntry);

      // Attach new node to chain
      if (newPosition == 1)
      {
```

# Revised Node and LinkedList Classes (7 of 11)

**Listing C4-3 [Continued]**

```
    // Insert new node at beginning of chain
    newNodePtr->setNext(headPtr);
    headPtr = newNodePtr;
}
else
{
    // Find node that will be before new node
    auto prevPtr = getNodeAt(newPosition - 1);

    // Insert new node after node to which prevPtr points
```

# Revised Node and LinkedList Classes (8 of 11)

**Listing C4-3 [Continued]**

```
        // Insert new node after node to which prevPtr points
        newNodePtr->setNext(prevPtr->getNext());
        prevPtr->setNext(newNodePtr);
     }  // end if

     itemCount++;  // Increase count of entries
  }  // end if

  return ableToInsert;
}  // end insert
```

**Listing C4-4** The remove method for **LinkedList**

```
template<class ItemType>
bool LinkedList<ItemType>::remove(int position)
{
   bool ableToRemove = (position >= 1) && (position <= itemCount);
   if (ableToRemove)
   {
      if (position == 1)
      {
         // Remove the first node in the chain
         headPtr = headPtr->getNext();
      }
      else
      {
         // Find node that is before the one to delete
```

# Revised Node and LinkedList Classes 

**Listing C4-4 [Continued]**

```
        // Find node that is before the one to delete
        auto prevPtr = getNodeAt(position - 1);

        // Point to node to delete
        auto curPtr = prevPtr->getNext();

        // Disconnect indicated node from chain by connecting the
        // prior node with the one after
        prevPtr->setNext(curPtr->getNext());
    }  // end if

    itemCount--;  // Decrease count of entries
}  // end if

return ableToRemove;
//  end remove
```

# Revised Node and LinkedList Classes (11 of 11)

**clear** method for **LinkedList**

```
template<class ItemType>
void LinkedList<ItemType>::clear()
{
   headPtr = nullptr;
   itemCount = 0;
}  // end clear
```

# Using Unique Pointers (1 of 3)

Different ways to create unique pointers.

```
std::unique_ptr<MagicBox<std::string>> myMagicPtr(
                                        new MagicBox<std::string>());
auto myToyPtr = std::make_unique<ToyBox<std::string>>(); // C++14 and
                                                          // later only
std::unique_ptr<MagicBox<std::string>> myFancyPtr; // Empty unique_ptr
```

# Using Unique Pointers (2 of 3)

Function that accepts ownership of an object and then returns it to the caller

```
// This method's return type is the type of the object returned.
auto changeBoxItem(std::unique_ptr<PlainBox<std::string>> theBox,
                   std::string theItem)
{
   theBox->setItem(theItem);
   return theBox;  // theBox surrenders ownership
} // end changeBoxItem
```

# Using Unique Pointers (3 of 3)

- A unique pointer …
  - Has solitary ownership of its managed object
  - Behaves as if it maintains a reference count of either 0 or 1 for its managed object
  - Can transfer its unique ownership of its managed object to another unique pointer using method move
  - Cannot be assigned to another unique pointer

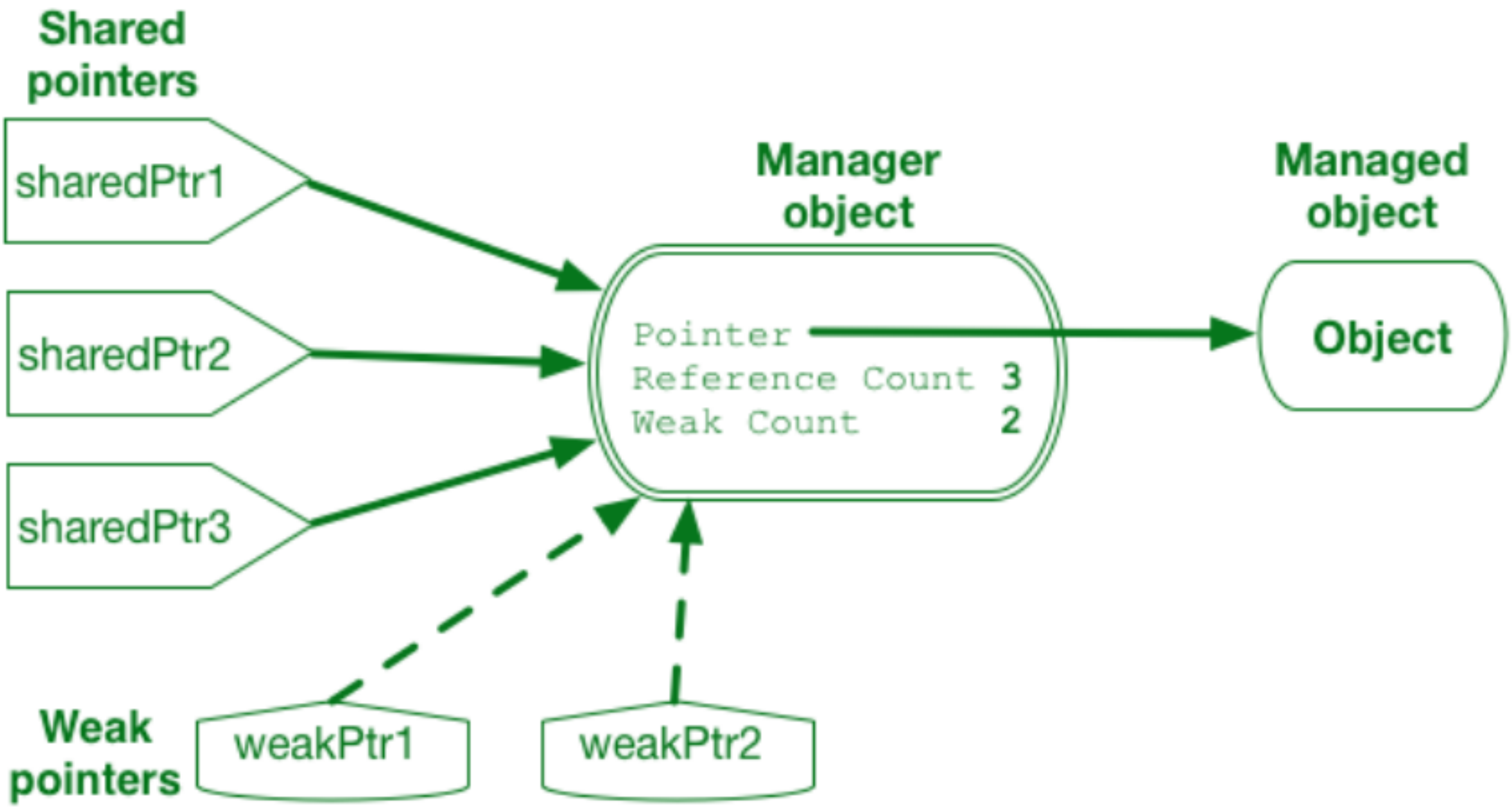
# Using Weak Pointers (1 of 4)

- Weak pointer only **observes** managed object
  - But does not have ownership
  - Therefore, cannot affect its lifetime
- After these statements execute, reference count for object managed by **sharedPtr1** is 3

```
auto sharedPtr1 = std::make_shared<MagicBox<std::string>>();
auto sharedPtr2 = sharedPtr1;
auto sharedPtr3 = sharedPtr1;
std::weak_ptr<MagicBox<std::string>> weakPtr1 = sharedPtr1;
auto weakPtr2 = weakPtr1;
```

# Using Weak Pointers (2 of 4)

**Figure C4-2** Weak and shared ownership of a managed object



# Using Weak Pointers (3 of 4)

**Listing C4-5** Partial header file for the class DoubleNode

```
template<class ItemType>
class DoubleNode
{
private:
   ItemType item;                                     // A data item
   std::shared_ptr<DoubleNode<ItemType>> next;    // Pointer to next node
   std::weak_ptr<DoubleNode<ItemType>> previous; // Pointer to previous
node
public:
   // Constructors, destructors, and methods
}; // end DoubleNode
```

# Using Weak Pointers (4 of 4)

- A weak pointer …
  - References but does not own an object referenced by shared pointer
  - Cannot affect lifetime of managed object
  - Does not affect reference count of managed object
  - Has method lock to provide a shared-pointer version of its reference
  - Has method expired to detect whether its reference object no longer exists

# Other Smart Pointer Features (1 of 2)

- Method common to all smart pointers
  - **reset**
- Method common to all shared and unique pointers
  - **get**
- Methods exclusive to shared pointers
  - **unique**
  - **use_count**

# Other Smart Pointer Features (2 of 2)

- Method exclusive to unique pointers
  - **release**
- Unique pointers with arrays
  - Use a unique pointer to manage a dynamic array