Chapter 10: C++ Dynamic Memory

Dynamic Memory Classes
Dynamic Memory Errors
In-class Work
Proper Memory Management

Classes which must allocate memory must manage it properly. Default behavior of operations in C++ are insufficient for this.

- The assignment operation will not perform a “deep copy” of structures linked with pointers.
- Rather, the pointers themselves will be copied, leading to shared memory.
- Shared memory requires reference counting to be properly deallocated. This is hard to program.
- C++ objects will not even deallocate memory they have allocated themselves unless made to do so by the programmer.
Proper Memory Management

- A class must deallocate memory it allocates. Each object, when its lifetime is over, should free any memory it has used.

- A class must copy, not share, referenced object data when an existing object is being assigned a value from another object.

- A class must copy, not share, referenced object data when a new object is being created using the value of another.
The destructor for a class is a special member function written to perform any cleanup work at the end of an object’s lifetime. If no such special work is necessary, a destructor need not be provided.

A destructor is required for dynamic memory classes to prevent a memory leak (an object must deallocate any memory it has allocated when it has done its work).

The destructor’s name is tilde ( ~ ) followed by the class name.

It takes no parameters, doesn’t have a return type.

It is called automatically when an object goes out of scope.

It is called automatically when the delete operator is called for a pointer to an object in that class.
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Copy Constructor

- When a constructor for a class is called with an existing object of the class as an actual parameter, the data members are copied into the memory allocated for the new object.

- In C++, this is the behavior of the default copy constructor.

- What will not happen automatically is a deep copy of the memory pointed to by data members which are pointers.

- To force a deep copy, the copy constructor must be explicitly defined for the class.

- The copy constructor is called when an instance of a class is passed by value to a function.

- To prevent the code from using the copy constructor, declare it as private.
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When an existing object of a class is assigned a value which is an existing object of the class, the data members are copied into the memory of the assigned-to object.

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To force a deep copy, the assignment operator, `operator=`, must be explicitly defined for the class.
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To force a deep copy, the assignment operator, operator=, must be explicitly defined for the class.
Example Dynamic Array Class: List

// List.h
#ifndef __LIST_H__
#define __LIST_H__

class List {

public:

    List(size_t capacity=10); // constructor
    List(const List &a); // copy constructor
    ~List(); // destructor

    int& operator[](size_t pos); // bracket operator
    List& operator=(const List &a); // assignment
    List& operator+=(const List &a); // += operator

    void append(int item);
    size_t size() const { return size_; }
private:
    void copy(const List &a);
    void resize(size_t new_size); // larger array
    int *data_; // dynamic array
    size_t size_; // size of dynamic array
    size_t capacity_; // capacity of dynamic array
};

// List.cpp
Definition of constructor:
List::List(size_t capacity)
{
    data_ = new int[capacity];
    capacity_ = capacity;
    size_ = 0;
}
Example Dynamic Array Class: List

Definition of destructor:

List::~List() {
    delete [] data_;  
}

**Example Dynamic Array Class: List**

*Definitions of copy constructor and of copy method:*

```cpp
List::List(const List &list) {
    copy(list);
}

void List::copy(const List &list) {
    size_t i;
    size_ = list.size_;  
capacity_ = list.capacity_;  
data_ = new int[list.capacity_];
    for (i=0; i<list.capacity_; ++i) {
        data_[i] = list.data_[i];
    }
}
```
**Example Dynamic Array Class: List**

*Definition of the assignment operator:*

```c++
List& List::operator=(const List &list)
{
    if (&list != this) {
        // deallocate existing dynamic array
        delete [] data_;
        // copy the data
        copy(list);
    }
    return *this;
}
```

The identifier `this` is an implicit pointer to the object with which the method is called. By returning `*this`, we are returning the `List` object that we just assigned. This definition allows us to write the chained form of the assignment statement e.g. `b=c=d`
Reference return types are allowed only when a function returns the address of data that will still be there after the function call is finished. (This disallows returning a reference to a local variable.) You can return a reference to a data member (attribute) of an object in the class to which the member function belongs. In the List class, this is done in the implementation of the [] operator to allow indexed data to be on the left side of an assignment statement, as in

```c++
List l(3);
l[0] = 0;
l[1] = 1;
l[2] = 2;
```
Definition of indexing operator

```cpp
inline int& List::operator[](size_t pos) {
    return data_[pos];
}
```
When memory that has been allocated is not deallocated in some scenario, then each time the scenario occurs another chunk of memory becomes unavailable to the system which is trying to reuse memory. This can happen thousands or millions of times. As it gets harder to find available memory when it is needed, the operating system tries to use the disk drive to keep memory it is using (this is called paging or swapping). This slows the system down, since disk access is much slower than semiconductor memory. Eventually the system crashes.

Memory leaks are hard to find and fix, and exist on commercially sold software. Rebooting your PC every once in a while can sometimes relieve this problem.
MEMORY LEAKS

// This code is incorrect
{
    int *x;
    x = new int;
    *x = 3;
    x = new int;
    *x = 4;
    delete x;
}
Accessing invalid memory means reading or writing on memory which has been deallocated (and reallocated for a different task).

This leads to unpredictable and incorrect behavior in a program.

Reading such data will produce garbage since the memory has been reallocated and reused by a different task running at the same time.

Writing on such memory will cause the task which now uses it to crash, since its contents have been changed.
Accessing Invalid Memory

```cpp
int main() // This program is incorrect
{
    int *y = new int;
    delete y;
    *y = 3;
    return 0;
}
```
In-class work

using testList.cpp write the program that does the following:

(I)
1) Creates an array of 20 elements,
2) fills it with \(1^2, 2^2, \ldots, (20)^2\),
3) displays it,
4) then adds all of them and displays the sum, then

(II) then
5) Define a friend function `cin` for `List` class,
6) Ask the user for a size of an array (how many values the user plans to enter),
7) Create an array of capacity = 10 * size,
8) Get the numbers from the user to store in the array,
9) add 10 to each member of the array and display it.