CL2001	Lab 1
Data Structures Lab	Revision Of Advanced OOP Concepts

NATIONAL UNIVERSITY OF COMPUTER AND EMERGING SCIENCES

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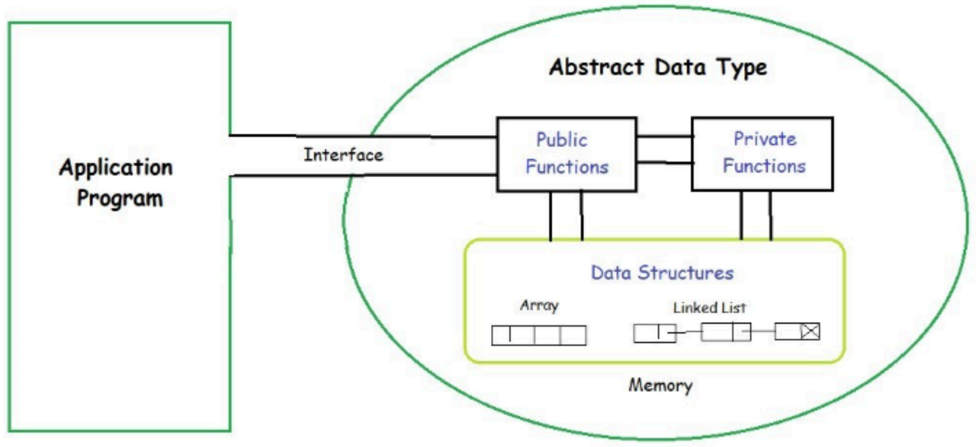
Lab Content

1. Introduction to Abstract Data Types (ADTs)
2. Memory Management in C++ (Pointers, Dynamic Memory Allocation)
3. Constructors & Destructors in C++
4. Rule of Three in C++

Abstract Data Types

Abstract Data Types (ADTs) are theoretical concepts that define the structure and behavior of data. An ADT defines a data structure by the operations that can be performed on it, not by how these operations are implemented. C++ classes are often used to implement ADTs.

This image demonstrates how an Abstract Data Type (ADT) hides internal data structures (like arrays, linked lists) using public and private functions, exposing only a defined interface to the application program.



Pointers in C++

Pointers are a core feature of C++ that allows you to directly manage memory. A pointer holds the memory address of another variable. Understanding pointers is critical for dynamic memory allocation and manipulation of data structures like linked lists and trees.

- **Pointer Basics**:
  - A pointer holds the address of a variable.
  - You can dereference a pointer to access the value stored at the address it points to.

```cpp
#include <iostream>
using namespace std;

int main() {
    int a = 10;
    int *ptr;  // pointer declaration
    ptr = &a;  // storing address of 'a' in 'ptr'

    cout << "Value of a: " << a << endl;
    cout << "Address of a: " << &a << endl;
    cout << "Value stored in ptr (address of a): " << ptr << endl;
    cout << "Value pointed by ptr: " << *ptr << endl;  // dereferencing

    return 0;
}
```

Dynamic Memory Allocation in C++

In C++, **stack memory** is automatically allocated for variables at compile time and has a fixed size. For greater control and flexibility, dynamic memory allocation on the **heap** is used, allowing manual allocation with new and deallocation with delete.

Dynamic memory allocation allows you to allocate memory at runtime using the **new** keyword. This is particularly useful for creating data structures where the size is not known at compile time, like linked lists or arrays where the size is determined by the user input.

- **Using new and delete:**
    - **new** allocates memory dynamically.
    - **delete** is used to deallocate memory and prevent memory leaks.

Code for Allocation Of Single Block (Single Variable)

```cpp
#include <iostream>
using namespace std;

int main() {
    // Dynamically allocating memory for a single integer
    int* ptr = new int;

    // Assigning a value to the dynamically allocated memory
    *ptr = 100;

    // Displaying the value stored at the allocated memory
    cout << "Value of the dynamically allocated integer: " << *ptr <<
endl;

    // Freeing the dynamically allocated memory
    delete ptr;
    return 0;
}
```

Dynamic Memory Allocation for 1D Array

```
#include <iostream>
using namespace std;

int main() {
    int* arr;
    int n;

    // Asking the user for the number of elements
    cout << "Enter the number of elements in the array: ";
    cin >> n;

    // Dynamically allocating memory for an array of integers
    arr = new int[n];

    // Taking input for each element of the array
    for (int i = 0; i < n; i++) {
        cout << "Enter element " << i + 1 << ": ";
        cin >> arr[i];
    }

    // Displaying the elements of the array
    cout << "Array elements: ";
    for (int i = 0; i < n; i++) {
        cout << arr[i] << " ";
    }
    cout << endl;

    // Freeing the dynamically allocated memory
    delete[] arr;

    return 0;
}
```

Deep & Shallow Copy

In general, creating a copy of an object means to create an exact replica of the object having the same literal value, data type, and resources. There are two ways that are used by C++ compilers to create a copy of objects.

- Copy constructor
- Assignment Operator

```
#copy constructor called
Object obj1(obj);
     //OR
Object obj1 = obj;

#assignment operator called
Object obj1;
obj1 = obj;
```

In C++, **copying an object** may seem simple at first, but it becomes tricky when the object involves **dynamically allocated memory (DMA)**. When you create a **copy of an object**, you generally have two options:

1. **Shallow Copy**: This is the default behavior in C++ when an object is assigned to another object or passed by value. A **shallow copy** means that **only the pointers are copied**, not the actual data. Both the original and the copy will share the same dynamically allocated memory. This can lead to problems such as:

    ○ **Double-deletion**: Both objects may attempt to free the same memory when they are destroyed, leading to **undefined behavior** (e.g., crashes or memory corruption).

    ○ **Data corruption**: If one object modifies the dynamically allocated memory, the changes will be reflected in the other object, which might not be the desired behavior.

```
class Box {
public:
    int* size;
    Box(int s) {
        size = new int(s); // Allocate memory dynamically
    }
    ~Box() {
        delete size; // Free the memory
    }
};

Box box1(10);
Box box2 = box1; // Shallow copy: box2.size points to the same memory as
box1.size
```

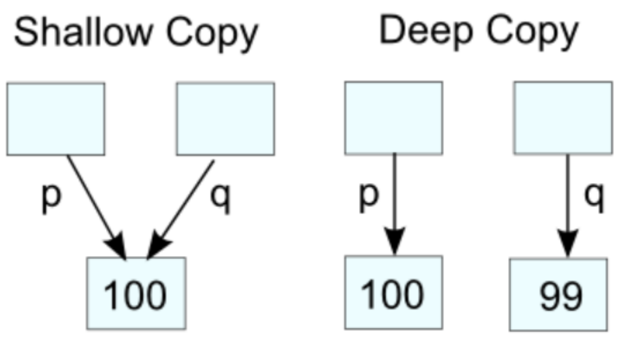
2. **Deep Copy**: A deep copy involves copying not just the pointer, but also the data that the pointer points to. This means creating a new memory block and copying the data from the original object into the new block. After a deep copy, the **original and the copied objects do not share memory**, and thus changes to one object's data do not affect the other.

```
class Box {
public:
    int* size;
    Box(int s) {
        size = new int(s); // Allocate memory dynamically
    }

    // Deep copy constructor
    Box(const Box& other) {
        size = new int(*other.size); // Create a new memory block and
copy data
    }

    ~Box() {
        delete size; // Free the memory
    }
};

Box box1(10);
Box box2 = box1; // Deep copy: box2.size gets its own memory
```



Rule of Three in C++

When **Dynamic Memory Allocation (DMA)** is used, we must ensure that our **objects are copied properly** to avoid issues like double-deletion or resource sharing.

The Rule of Three in C++ suggests that **if you define any one of the following three functions**, you should **define all three**. These three functions help ensure proper handling of resources during copying and assignment, especially when DMA is involved:

1. **Destructor**: Cleans up dynamically allocated resources (memory, file handles, etc.) when an object goes out of scope or is explicitly deleted.
    - **Why it's important**: If you don't define a destructor, the **default destructor** may not free the dynamically allocated memory, leading to **memory leaks**.
2. **Copy Constructor**: Creates a **deep copy** of an object when it is passed by value or returned by value.
    - **Why it's important**: Without a custom copy constructor, C++ will perform a **shallow copy** by default, which can lead to **double-deletion** or **data corruption** when objects are destroyed.
3. **Copy Assignment Operator**: Assigns one object's values to another object (already created), ensuring a **deep copy** if necessary.
    - **Why it's important**: Without a custom copy assignment operator, the default **shallow assignment** is performed, which can lead to **resource conflicts**, **double-deletion**, or **incorrect data sharing** between objects.

LAB TASKS

Q1. Suppose you are developing a bank account management system, and you have defined the BankAccount class with the required constructors. You need to demonstrate the use of these constructors in various scenarios.

1. Default Constructor Usage: Create a default-initialized BankAccount object named account1. Print out the balance of account1.
2. Parameterized Constructor Usage: Create a BankAccount object named account2 with an initial balance of $1000. Print out the balance of account2.
3. Copy Constructor Usage: Using the account2 you created earlier, create a new BankAccount object named account3 using the copy constructor. Deduct $200 from account3 and print out its balance. Also, print out the balance of account2 to ensure it hasn't been affected by the transaction involving account3.

Q2. Create a C++ class named "Exam" using **DMA** designed to manage student exam records, complete with a shallow copy implementation? Define attributes such as student name, exam date, and score within the class, and include methods to set these attributes and display exam details. As part of this exercise, intentionally omit the implementation of the copy constructor and copy assignment operator. Afterward, create an instance of the "Exam" class, generate a shallow copy, and observe any resulting issues?

Q3. Create a C++ class Box that uses dynamic memory allocation for an integer. Implement the Rule of Three by defining a destructor, copy constructor, and copy assignment operator. Demonstrate the behavior of both shallow and deep copy using test cases.