CL2001 Data Structure Lab	Lab 2 1D and 2D Dynamic Safe Pointers and jagged array

NATIONAL UNIVERSITY OF COMPUTER AND EMERGING SCIENCES

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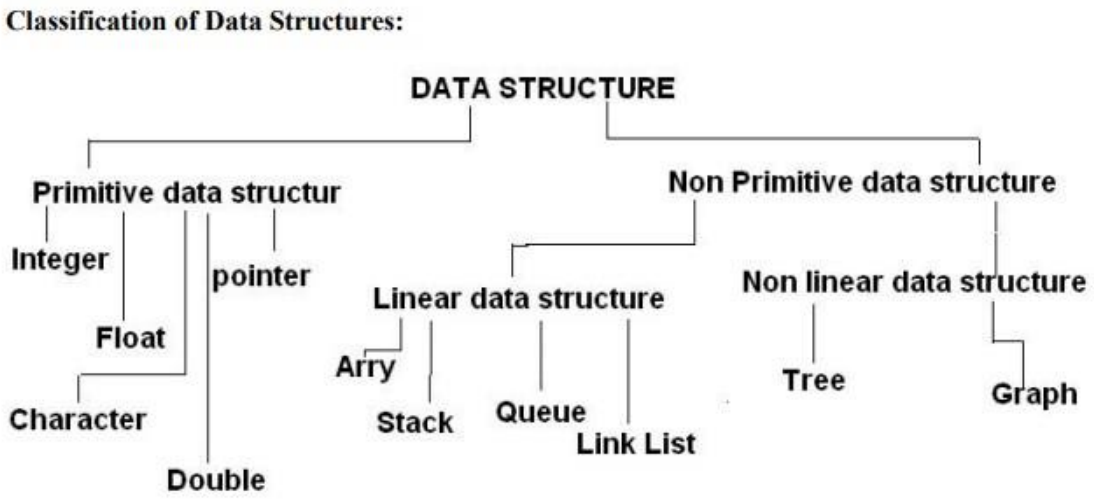
Lab Content

1. 1D and 2D static Array
2. 1D and 2D Dynamic Arrays
3. Safe Arrays
4. Jagged Array

Data Structure

A data structure is a way of organizing and storing data in a computer so that it can be used efficiently.
Think of it as a container that holds data in a particular arrangement so that operations like searching, inserting, deleting, or sorting can be done quickly. **Below is the classification of data structure:**



Linear Data Structures

A Linear Data Structure is a type of data structure in which data elements are arranged sequentially (one after another). For Example: Arrays, linked lists, stacks and queues. In a linear data structure, every element has a unique predecessor and a unique successor (except the first and last element).

Characteristics of Linear Data Structures:

1. **Sequential organization** - elements are stored in a sequence.
2. **Single level** - data flows in one dimension (like a straight line).
3. **Traversal** - elements are visited one by one.
4. **Memory allocation** - can be contiguous (**arrays**) or non-contiguous (**linked lists**).

Arrays

An array is a collection of elements of the same data type, stored in contiguous (continuous) memory locations. It allows us to store and access multiple values using a single variable name with an index.

Key Features of Arrays

- Stores multiple values of the same type.
- Elements are stored in contiguous memory.
- Index-based access (fast lookup).
  - Index starts from 0 (first element).
  - Last element index = size – 1.
- Fixed size (once created, size cannot change).

1D and 2D arrays

1D array: a simple list of elements

int arr[5] = {10, 20, 30, 40, 50};

Memory:

Index: 0 1 2 3 4

Value: 10 20 30 40 50

2D array: Like a tabe (rows x columns)

```
int matrix[2][3] = {
  {1, 2, 3},
  {4, 5, 6}
};
```

Memory:

Row 0 → [1 2 3]

Row 1 → [4 5 6]

1D array Example

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

int main() {
    int arr[5] = {10, 20, 30, 40, 50};

    cout << "1D Array elements: ";
    for (int i = 0; i < 5; i++) {
        cout << arr[i] << " ";
    }
    return 0;
}
```

2D array Example

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

int main() {
    int matrix[2][3] = {
        {1, 2, 3},
        {4, 5, 6}
    };

    cout << "2D Array elements:\n";
    for (int i = 0; i < 2; i++) {
        for (int j = 0; j < 3; j++) {
            cout << matrix[i][j] << " ";
        }
        cout << endl;
    }
    return 0;
}
```

Dynamic arrays

A 1D array is just a list of elements stored sequentially in memory. A dynamic array means the array size is not fixed at compile-time but is allocated at runtime using pointers and the new operator. Memory can be allocated and later freed using delete[].

Example 1D dynamic array

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

int main() {
    int n;
    cout << "Enter size of 1D array: ";
    cin >> n;

    // 1D Dynamic array
    int* arr = new int[n];   // allocate memory dynamically

    cout << "Enter " << n << " elements:\n";
    for (int i = 0; i < n; i++) {
        cin >> arr[i];
    }

    cout << "You entered: ";
    for (int i = 0; i < n; i++) {
        cout << arr[i] << " ";
    }

    delete[] arr;
    return 0;
}
```

2D Dynamic array

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

int main() {
    int rows, cols;
    cout << "Enter rows and cols: ";
    cin >> rows >> cols;

    // 2D Dynamic array
    int** arr = new int*[rows];    // array of row pointers
    for (int i = 0; i < rows; i++) {
        arr[i] = new int[cols];    // each row has 'cols' elements
    }

    cout << "Enter elements (" << rows << "x" << cols << "):\n";
    for (int i = 0; i < rows; i++) {
        for (int j = 0; j < cols; j++) {
            cin >> arr[i][j];
        }
    }

    cout << "Matrix:\n";
    for (int i = 0; i < rows; i++) {
        for (int j = 0; j < cols; j++) {
            cout << arr[i][j] << " ";
        }
        cout << endl;
    }

    // free memory
    for (int i = 0; i < rows; i++) {
        delete[] arr[i];
    }
    delete[] arr;

    return 0;
}
```

Resizing dynamic the arrays

```
int main() {

    int size = 5;
    int* arr = new int[size]{1, 2, 3, 4, 5};

    cout << "Original array: ";
    for (int i = 0; i < size; i++) cout << arr[i] << " ";
    cout << "\n";

    int newSize = 8;
    arr = resizeArray(arr, size, newSize);

    // Fill new elements
//    for (int i = size; i < newSize; i++) {
//        arr[i] = (i + 1) * 10;  // 60, 70, 80
//    }

 for (int i = size; i < newSize; i++) {
    cin>>arr[i];
    }
    cout << "Resized to bigger array: ";
    for (int i = 0; i < newSize; i++) cout << arr[i] << " ";
    cout << "\n";

    size = newSize;
    newSize = 3;
    arr = resizeArray(arr, size, newSize);

    cout << "Resized to smaller array: ";
    for (int i = 0; i < newSize; i++) cout << arr[i] << " ";
    cout << "\n";

    delete[] arr;
    return 0;
}
```

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

int* resizeArray(int* oldArr, int oldSize, int newSize) {

    if (newSize == oldSize) {
        return oldArr;
    }

    int* newArr = new int[newSize];

    int limit = (oldSize < newSize) ? oldSize : newSize;
    for (int i = 0; i < limit; i++) {
        newArr[i] = oldArr[i];
    }

    delete[] oldArr;

    return newArr;
}
```

Safe Array

In C++, when you create a normal array (static or dynamic), there is no **automatic bounds** checking.

```
int arr[5];
arr[10] = 100;   // ? Undefined behavior (out of range)
```

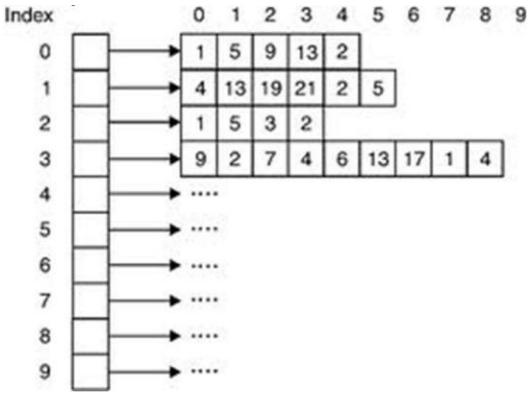
What will happen by executing above line?

Solution of above is safe array that Validates the index before accessing or modifying elements. Prevents writing outside the valid range. Optionally allows custom index ranges (like starting from -5 instead of 0). **See Example below:**

```
void set(int pos, Element val) {
    // check if position is valid
    if (pos < 0 || pos >= size) {
        cout << "Boundary Error\n";
    }
    else {
        Array[pos] = val;   // safe assignment
    }
}
```

Jagged Array

A Jagged Array is like a 2D array but each row can have a different number of columns.



Example:

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

int main() {
    int rows = 3;
    int **arr = new int*[rows];  // pointer to pointer (for jagged array)
    int Size[3];


    for (int i = 0; i < rows; i++) {
        cout << "Enter size of Row " << i + 1 << ": ";
        cin >> Size[i];
        arr[i] = new int[Size[i]]; // allocate each row with different size
    }
    for (int i = 0; i < rows; i++) {
        cout << "Enter " << Size[i] << " elements for Row " << i + 1 << ": ";
        for (int j = 0; j < Size[i]; j++) {
            cin >> arr[i][j];  // easier notation instead of pointer arithmetic
            //cin >> *(*(arr + i) + j);

        }
    }
    cout << "\nJagged Array Elements:\n";
    for (int i = 0; i < rows; i++) {
        cout << "Row " << i + 1 << ": ";
        for (int j = 0; j < Size[i]; j++) {
            cout << arr[i][j] << " ";
        }
        cout << endl;
    }

    for (int i = 0; i < rows; i++) {
        delete[] arr[i];  // free each row
    }
    delete[] arr;  // free row pointers

    return 0;
}
```

LAB TASKS

Task #1:
Implement a program that dynamically allocates a 1D array of integers.

=> The size should be given by the user.
=> Initialize all elements with zero.
=> Then, let the user update values at different positions.
=> Finally, print the array and deallocate memory properly.

Task #2:
Write a program that uses a dynamic 2D array to represent a seating chart in a classroom.

=> Rows represent benches, columns represent seats on each bench.
=> Initialize the array with 0 (empty).
=> Let the user fill seats (1 for occupied).
=> Print the final seating chart in matrix form.

Task #3:
Design a program to handle marks of students in different courses using a jagged array (since each student is enrolled in a different number of courses).

=> Input the number of courses each student takes.
=> Dynamically allocate memory for each student accordingly.
=> Calculate and display each student's average marks.

Task #4:
Create a dynamic program that manages monthly expenses for a family.

=> Use a 1D dynamic array to store expenses for n months.
=> Add a feature to resize the array if the user wants to track more months later.
=> Compute and display the total and average expenses.

Task #5:
Write a C++ program that dynamically creates a 2D matrix and provides:

=> Addition of two matrices.
=> Subtraction of two matrices.
=> Ensure safe memory handling with proper allocation/deallocation.

Task #6:
Implement a Safe Pointer class to wrap around an integer pointer.

=> Provide methods for setValue(), getValue(), and release().
=>
Demonstrate the class by storing marks of 5 students and printing them safely without direct pointer manipulation.

Task #7:
A company has multiple departments, each department has a different number of employees.

=> Use a jagged array where each row corresponds to a department and columns store employee salaries.
Calculate:
-> The highest salary in each department.
-> The department with the overall maximum average salary.

Task #8:
Create a dynamic program to store temperature readings of a city for n days and m different times in a day using a 2D array.

=> Calculate the daily average temperature.
=> Find the hottest and coldest day.

Task #9:
Implement a program to represent a sparse matrix using a dynamic 2D array.

=> Input matrix elements.
=> Display the matrix in normal form.
=> Display the matrix in compressed form (row, column, value).

Task #10:
Design a program that maintains library book records using dynamic arrays.

=> Each row represents a category (e.g., Fiction, Science, History).
=> Each category has a different number of books (use a jagged array).
=> Store book IDs dynamically and allow the user to search for a given book ID.
=> Print whether the book is available and in which category.