Lab Assignment 1
Dynamic Growing Arrays in C++

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Abstract

The lab consisted of implementation of dynamic array in C++, also known as vectors. The program made for this lab was an interactive menu that allowed the user to perform different task on a vectors, which include the initialization, the increase in allocated memory for the vector, adding/remove elements to either the end of the list or at any given index, shrinking the size of the vector by freeing up unused memory and printing the current elements of the vector. This allowed an array to not have a set number of elements, allowing for the user to just keep adding elements without worry of the adding an element that is outside of the bounds of the static array.

Introduction

Before this lab, any array that were used in any of the programs were static, meaning that the size of the array was set within the initialization of the array. This meant that the array wouldn't have much flexibility later on, when any changes to the program would inevitably come. With this lab, dynamic arrays, or vectors, were introduced and implements in C++. With this vector, it gave the user the ability to keep adding elements to an array without having to worry about adding an element to an index that was not in the initial array. With the implementation of vectors, previous knowledge about pointers to elements and how to reference them is necessary, since the pointers are what allow us to keep referencing and allocating memory to the initialized array.

Lab Discussion

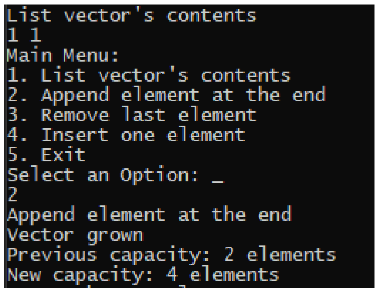
Equipment used in this lab include

- Zedboard (ZYNQ SoC)
    - Dual ARM Cortex – A9 MPCore with CoreSight
    - Zynq-7000 AP SoC XC7Z020-1CLG484
- Xillinux OS
- CoE lab desktop

Results and Analysis

Assignment 1.1 – Growing the vector

```
void Grow(){
    int new_size = size * 2;
    double *new_array = new double[new_size];

    for(int i = 0; i < size; i++){
        new_array[i] = array[i];
    }

    Finalize();
    array = new_array;
    cout << "Vector grown" << endl;
    cout << "Previous capacity: " << size << " elements" << endl;
    cout << "New capacity: "<< new_size << " elements" << endl;
    size = new_size;
}
```



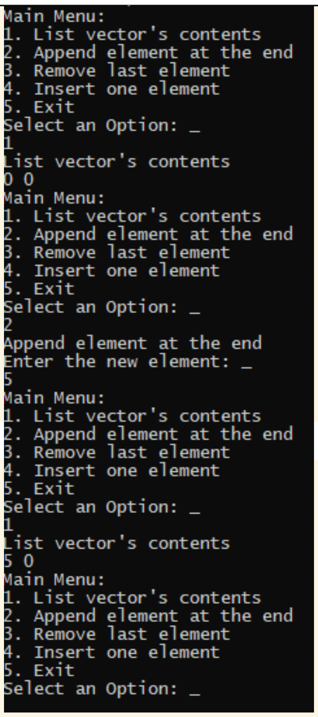
```
List vector's contents
1 1
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
2
Append element at the end
Vector grown
Previous capacity: 2 elements
New capacity: 4 elements
```

Figure 1 - Output when growing a vector

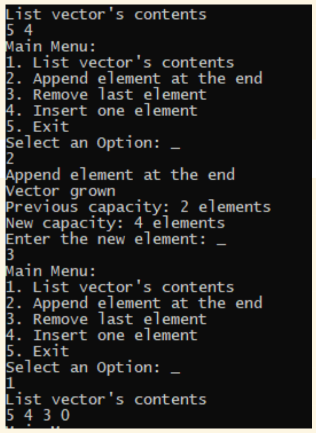
One of the cornerstones of vectors are their ability to dynamically grow in size when needed. The function `Grow()` is what allows that by setting a new size equal to double of the previous size. Once the new size is calculated, a pointer to a new array is made, which has the new size. Once that array is initialized, all the elements of the old array are copied into the new one, leaving the rest with a bunch of zeroes. When all the elements are copied over, the pointer for the old array is changed to the new one, so that it can still be referenced without much trouble. Since we don't want to take up any unnecessary space, the old array is deleted.

Assignment 1.2 – Adding an element to the end

```cpp
// add an element to the end of the vector
void AddElement(){
    if(size == count){
        Grow();
    }
    double new_element;
    cout << "Enter the new element: _" << endl;
    cin >> new_element;
    array[count] = new_element;
    count++;
}

// Print the vector
void PrintVector(){
    for(int i = 0; i < size; i++){
        cout << array[i] << " ";
    }
    cout << endl;
}
```



```
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
1
List vector's contents
0 0
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
2
Append element at the end
Enter the new element: _
5
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
1
List vector's contents
5 0
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
```



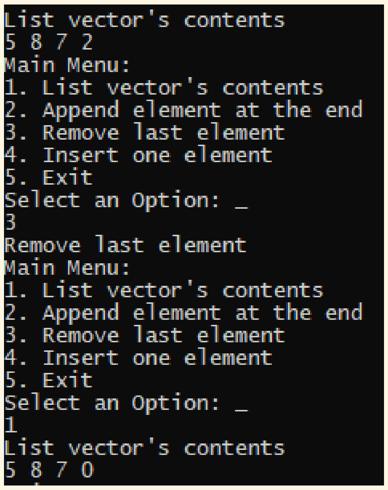
```
List vector's contents
5 4
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
2
Append element at the end
Vector grown
Previous capacity: 2 elements
New capacity: 4 elements
Enter the new element: _
3
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
1
List vector's contents
5 4 3 0
```

The `AddElement()` function is one of the main reasons for using a dynamic array. If the user wishes to add an element to an array that is not completely filled, it will just add the elements to the next empty index in the array. However, once `count` is equal to the `size` of the array, then the function knows to increase the size of the vector, since `count` is the total number of elements in the array, meaning that it will try to add the element to index `size`, an index that is out of bounds.

The `PrintVector()` goes to every single element in vector, assigned or not, and prints it. Since `size` is a global variable (something that is usually not recommended), it allows the program to reference it without the function needing an argument to know how large the array is.

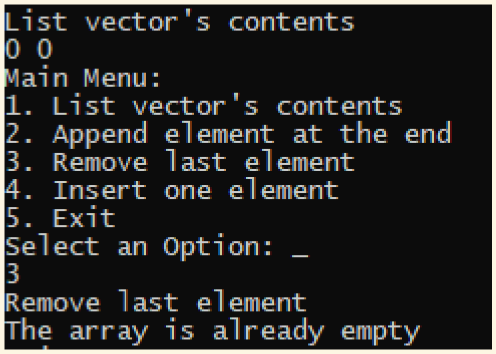
Assignment 1.3 – Removing an element from the end

```
void RemoveElement(){
    if(count>0){
        array[count-1] = 0;
        count--;
        if (size * 0.3 > count) {
            Shrink();
        }
    }
    else cout << "The array is already empty" << endl;
}
```



```
List vector's contents
5 8 7 2
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
3
Remove last element
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
1
List vector's contents
5 8 7 0
```

Figure 1. Removing an element from the end of the vector



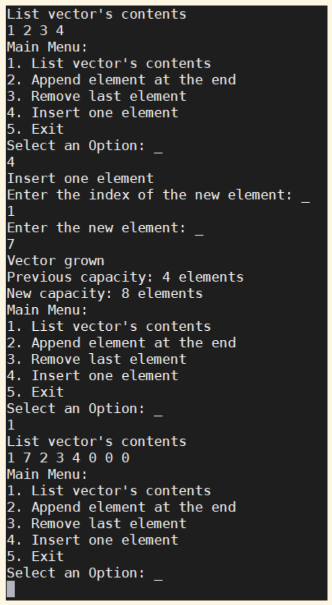
```
List vector's contents
0 0
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
3
Remove last element
The array is already empty
```

Figure 2. Removing an element from an empty vector

The `RemoveElement()` removes the last element of the vector by accessing the array at the index of the last assigned index, which is one less than the total number of elements, and setting it to zero. If the array is already filled with zeroes (meaning the vector is completely empty and `count` is zero), an error message is printed, telling the user that the vector is already empty and any more elements cannot be removed.

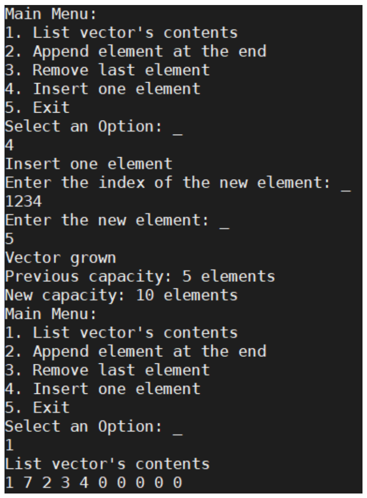
Assignment 1.4 – Inserting an element

```
void InsertElement(){
    int index;
    double new_element;
    cout <<"Enter the index of the new element: _" << endl;
    cin >> index;
    cout << "Enter the new element: _" << endl;
    cin >> new_element;

    if(size=count){ Grow(); }

    for(int i = count-1; i >= index; i--){
        array[i + 1] = array[i];
    }

    array[index] = new_element;
    count++;
}
```



```
List vector's contents
1 2 3 4
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
4
Insert one element
Enter the index of the new element: _
1
Enter the new element: _
7
Vector grown
Previous capacity: 4 elements
New capacity: 8 elements
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
1
List vector's contents
1 7 2 3 4 0 0 0
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
```

The InsertElement()takes an integer x as input for the index of the new element that is to be inserted and a double y as the actual new element from the user. It then checks if the size of the array is equal to the number of elements in it and if it is Grow is called to increase the size of the array. Then it systematically shifts the elements downward after where the new element is inserted and finally increases the count of elements

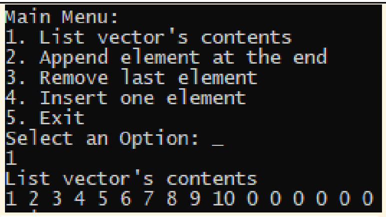


```
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
4
Insert one element
Enter the index of the new element: _
1234
Enter the new element: _
5
Vector grown
Previous capacity: 5 elements
New capacity: 10 elements
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
1
List vector's contents
1 7 2 3 4 0 0 0 0 0
```

Figure 2 . Output of InsertElement when an invalid index is input

Assignment 1.5 – Shrinking the vector

```
void Shrink(){
    double *new_array = new double[count];

    for(int i=0; i < count; i++){
        array[i] = new_array[i];
    }
    cout << "Vector shrinked" << endl;
    cout << "Previous capacity: " << size << "elements." << endl;
    cout << "New capacity: " << count << " elements." << endl;
    size = count;
    array = new_array;
}
```

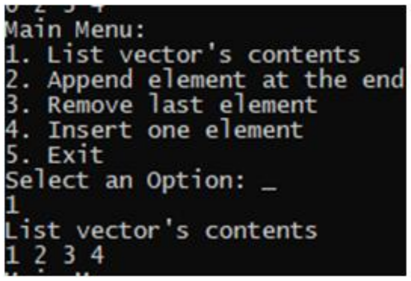


```
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
1
List vector's contents
1 2 3 4 5 6 7 8 9 10 0 0 0 0 0 0
```

Figure 3 . An array with 16 elements

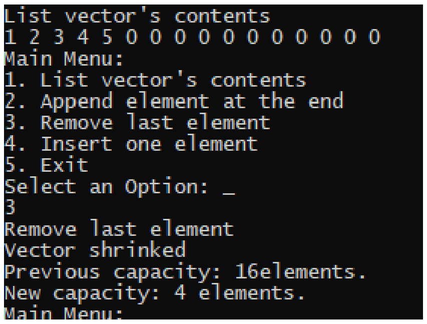
The Shrink() first initializes a new array with double elements, of size count (the number of elements in the current array) which is necessarily less than the size of the current array. It then

systematically replaces the elements of the new array with those of the old array until they are all replaced and then makes the new array the current array.



```
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
1
List vector's contents
1 2 3 4
```

Figure 4 . With 4 elements, vector shrinks to 4



```
List vector's contents
1 2 3 4 5 0 0 0 0 0 0 0 0 0 0 0
Main Menu:
1. List vector's contents
2. Append element at the end
3. Remove last element
4. Insert one element
5. Exit
Select an Option: _
3
Remove last element
Vector shrinked
Previous capacity: 16elements.
New capacity: 4 elements.
Main Menu:
```

Figure 5 . 30% of 16 of 4 elements

Conclusion

The use of dynamic arrays, or vectors, allow the user to add items to an array without having to assign an amount of space before hand resulting in that sometimes that that space is not enough. With vectors, the user now has the ability to add elements, even then the initialized array might not have had enough space.

References

[1] Michael Benjamin, “*Lab Report Guide*”, Northeastern University, January 18 2006.

Appendix

```
#include <iostream>
#include <string>
#include <vector>
#include <iomanip>

using std::cout;
using std::cin;
using std::endl;

    double *array;
    int count;
    int size;

    void Shrink();

    void Initialize() {
        count = 0;
        size = 2;
        array = new double[size];
    }

    void Finalize(){
        delete[] array;
    }

    void Grow(){
        int new_size = size * 2;
        double *new_array = new double[new_size];

        for(int i = 0; i < size; i++){
            new_array[i] = array[i];
        }

        Finalize();
        array = new_array;
        cout << "Vector grown" << endl;
        cout << "Previous capacity: " << size << " elements" << endl;
        cout << "New capacity: "<< new_size << " elements" << endl;
        size = new_size;
    }

    // add an element to the end of the vector
    void AddElement(){
        if(size == count){
            Grow();
        }
        double new_element;
        cout << "Enter the new element: _" << endl;
        cin >> new_element;
        array[count] = new_element;
        count++;
    }

    void RemoveElement(){
        if(count>0){
            array[count-1] = 0;
            count--;
            if (size * 0.3 > count) {
                Shrink();
            }
        }
        else cout << "The array is already empty" << endl;
    }

    void InsertElement(){
        int index;
        double new_element;
        cout <<"Enter the index of the new element: _" << endl;
        cin >> index;
        cout << "Enter the new element: _" << endl;
        cin >> new_element;

        if(size=count){
            Grow();
        }

        for(int i = count-1; i >= index; i--){
            array[i + 1] = array[i];
        }

        array[index] = new_element;
        count++;
    }

    void Shrink(){
        double *new_array = new double[count];

        for(int i=0; i < count; i++){
            array[i] = new_array[i];
        }
        cout << "Vector shrinked" << endl;
        cout << "Previous capacity: " << size << "elements." << endl;
        cout << "New capacity: " << count << " elements." << endl;
        size = count;
        array = new_array;
    }

    // Print the vector
    void PrintVector(){
        for(int i = 0; i < size; i++){
            cout << array[i] << " ";
        }
        cout << endl;
    }

    int main(){
        Initialize();
        int input;
        while (true){
            cout << "Main Menu:" << endl;
            cout << "1. List vector's contents" << endl;
            cout << "2. Append element at the end" << endl;
            cout << "3. Remove last element" << endl;
            cout << "4. Insert one element" << endl;
            cout << "5. Exit" << endl;
            cout << "Select an Option: _ " << endl;
            cin >> input;
            switch (input){
                case 1:
                    cout<<"List vector's contents"<<endl;
                    PrintVector();
                    break;
                case 2:
                    cout<<"Append element at the end"<<endl;
                    AddElement();
                    break;
                case 3:
                    cout<<"Remove last element"<<endl;
                    RemoveElement();
                    break;
                case 4:
                    cout<<"Insert one element"<<endl;
                    InsertElement();
                    break;
                case 5:
                    return(0);
                    break;
                default:
                    cout<<"Error: Invalid number"<<endl;
            }
        }
    }
```