Computer Graphics (UCS505)

Project on

Sorting Algorithm Visualizer

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1. Introduction to Project

This project visualizes various sorting algorithms using the OpenGL library. The goal is to help understand how sorting algorithms operate internally by showing real-time graphical transformations of data elements represented as vertical bars.

The program executes the following:

- Initializes the OpenGL graphics window.
- Generates an array of random numbers represented as bars of variable heights.
- Executes different sorting algorithms such as Quick Sort, Merge Sort, Selection Sort, and Bubble Sort.
- Visually shows the comparisons and swaps by updating the bars in real time.
- Displays the name of the algorithm currently running and the number of comparisons made.

2. Computer Graphics Concepts Used

- OpenGL: Used for rendering 2D graphics and drawing primitive shapes like rectangles.
- Transformation: Applied to dynamically update bar positions and heights during sorting.
- Modelling: Bars are modelled as rectangles with variable heights.
- Coloring: Different RGB colors are used to distinguish the text and bar visuals.
- Rendering: glFlush() is used to update the visual output immediately.
- Text Display: Uses rasterized bitmap fonts for displaying algorithm names and comparisons.

3. User Defined Functions

- **init():** Sets the background color and initializes the OpenGL environment.
- **displayText(x, y, text):** Displays a string at the specified screen coordinates.
- **drawbar(arr):** Clears the screen and redraws all bars based on the current array, updating in real-time.
- **Quicksort::**quicksort() / partition() / findpivot(): Implements quick sort and includes steps to count comparisons and show real-time updates.
- **Selection Sort: selectionsort():** Performs selection sort with comparison count tracking.
- **Bubble Sort: bubblesort():** Implements bubble sort with step-by-step visualization.
- **Merge Sort: mergesort() / merge():** Implements merge sort and visualizes merging steps.
- **display():** Calls each sorting algorithm one after another on the same dataset with delays in between.

2. Code

```
#include <GL/glut.h>
#include <windows.h>
#include <iostream>
#include <vector>
#include <string>
#include <ctime>

#define width 500
#define height 500

using namespace std;

string comparisontext = "No. of Comparisons";
string sort_name;
int comparison_count;
vector<int> arr(50); // Reduced from 500 to 50 for faster visualization

// Function for displaying text
void displayText(float x, float y, string stringToDisplay)
{
    glRasterPos2f(x, y);
    for (char c : stringToDisplay)
    {
        glutBitmapCharacter(GLUT_BITMAP_HELVETICA_18, c);
    }
}

// Display Initialization
void init()
{
    glClearColor(1.0f, 1.0f, 1.0f, 1.0f);
}

// Function to draw bars
void drawbar(vector<int> arr)
{
    glClear(GL_COLOR_BUFFER_BIT);
    glColor3f(0.0, 0.0, 0.0);
    displayText(190, 470, sort_name);
    displayText(150, 430, "No. of Comparisons = " + to_string(comparison_count));
    glColor3f(1.0, 0.0, 0.0);
    int barWidth = width / arr.size();
    int x = 0;
    for (int i = 0; i < arr.size(); i++)
    {
        glRecti(x, 0, x + barWidth - 1, arr[i]);
        x += barWidth;
    }
    glFlush();
    Sleep(10); // Reduced delay for smoother animation
}

// Quicksort structure
struct Quicksort
{
    int findpivot(vector<int>&, int, int, int);
    int partition(vector<int>&, int, int);
    void quicksort(vector<int>&, int, int);
};
```

```
int Quicksort::findpivot(vector<int>& sample, int left, int mid, int right)
{
    comparison_count++;
    drawbar(sample);
    if ((sample[left] >= sample[mid] && sample[left] <= sample[right]) ||
        (sample[left] <= sample[mid] && sample[left] >= sample[right]))
        return left;

    comparison_count++;
    drawbar(sample);
    if ((sample[mid] >= sample[left] && sample[mid] <= sample[right]) ||
        (sample[mid] <= sample[left] && sample[mid] >= sample[right]))
        return mid;

    comparison_count++;
    drawbar(sample);
    return right;
}

int Quicksort::partition(vector<int>& sample, int left, int right)
{
    int p = findpivot(sample, left, (left + right) / 2, right);
    swap(sample[left], sample[p]);
    drawbar(sample);
    p = sample[left];
    int i = left + 1;
    int j = left + 1;
    for (; i <= right; i++)
    {
        comparison_count++;
        if (sample[i] < p)
        {
            swap(sample[i], sample[j]);
            j++;
        }
        drawbar(sample);
    }
    swap(sample[left], sample[j - 1]);
    drawbar(sample);
    return j - 1;
}

void Quicksort::quicksort(vector<int>& sample, int left, int right)
{
    if (right > left)
    {
        int p = partition(sample, left, right);
        quicksort(sample, left, p - 1);
        quicksort(sample, p + 1, right);
    }
}

// Selection Sort
struct SelectionSort
{
    void selectionsort(vector<int>&);
};

void SelectionSort::selectionsort(vector<int>& sample)
{
    drawbar(sample);
```

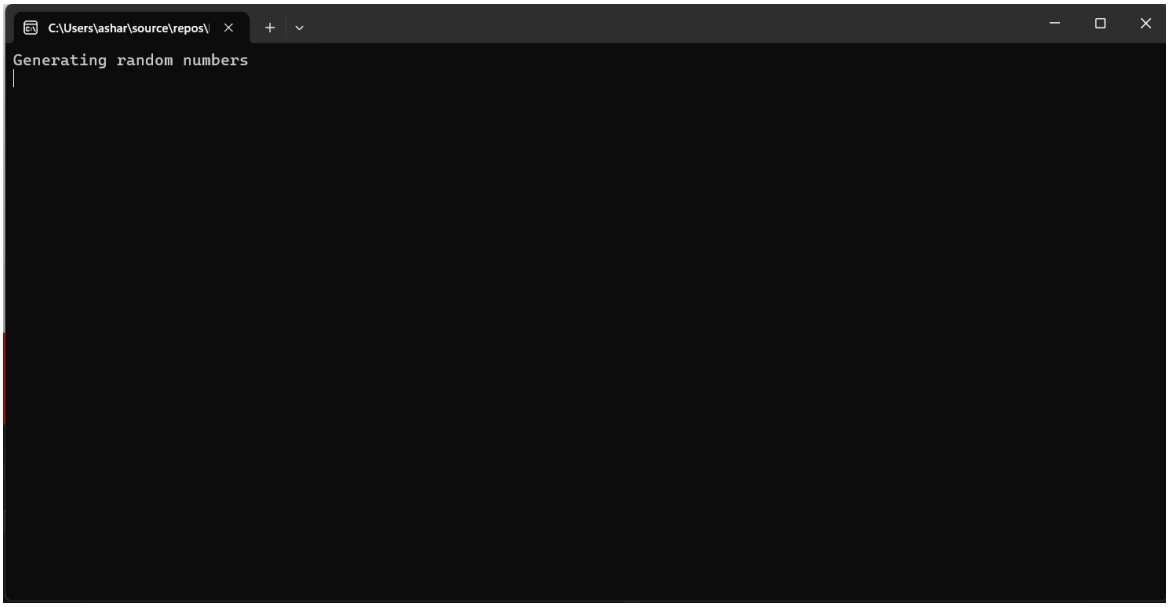
```
    int n = sample.size();
    for (int i = 0; i < n - 1; i++)
    {
        int min_idx = i;
        for (int j = i + 1; j < n; j++)
        {
            if (sample[j] < sample[min_idx])
                min_idx = j;
            comparison_count++;
            drawbar(sample);
        }
        swap(sample[min_idx], sample[i]);
        drawbar(sample);
    }
    drawbar(sample);
}

// Bubble Sort
struct BubbleSort
{
    void bubblesort(vector<int>&);
};

void BubbleSort::bubblesort(vector<int>& sample)
{
    drawbar(sample);
    int n = sample.size();
    for (int i = 0; i < n - 1; i++)
    {
        bool swapped = false;
        for (int j = 0; j < n - i - 1; j++)
        {
            if (sample[j] > sample[j + 1])
            {
                swap(sample[j], sample[j + 1]);
                swapped = true;
            }
            comparison_count++;
            drawbar(sample);
        }
        if (!swapped)
            break;
    }
    drawbar(sample);
}

// Merge Sort
struct MergeSort
{
    void merge(vector<int>&, int, int, int);
    void mergesort(vector<int>&, int, int);
};

void MergeSort::merge(vector<int>& sample, int l, int m, int r)
{
    drawbar(sample);
    int n1 = m - l + 1;
    int n2 = r - m;

    vector<int> l_sample(n1), r_sample(n2);

    for (int i = 0; i < n1; i++)
```

```
        l_sample[i] = sample[l + i];
    for (int j = 0; j < n2; j++)
        r_sample[j] = sample[m + 1 + j];

    int i = 0, j = 0, k = l;
    while (i < n1 && j < n2)
    {
        if (l_sample[i] <= r_sample[j])
        {
            sample[k++] = l_sample[i++];
        }
        else
        {
            sample[k++] = r_sample[j++];
        }
        comparison_count++;
        drawbar(sample);
    }

    while (i < n1)
    {
        sample[k++] = l_sample[i++];
        comparison_count++;
        drawbar(sample);
    }

    while (j < n2)
    {
        sample[k++] = r_sample[j++];
        comparison_count++;
        drawbar(sample);
    }
    drawbar(sample);
}

void MergeSort::mergesort(vector<int>& sample, int l, int r)
{
    if (l < r)
    {
        int m = l + (r - l) / 2;
        mergesort(sample, l, m);
        mergesort(sample, m + 1, r);
        merge(sample, l, m, r);
    }
}

// Display function
void display()
{
    glClear(GL_COLOR_BUFFER_BIT);
    vector<int> temp;

    temp = arr;
    Quicksort my_qsort;
    comparison_count = 0;
    sort_name = "Quick Sort";
    my_qsort.quicksort(temp, 0, temp.size() - 1);
    Sleep(2000);

    temp = arr;
    SelectionSort my_selsort;
    comparison_count = 0;
```

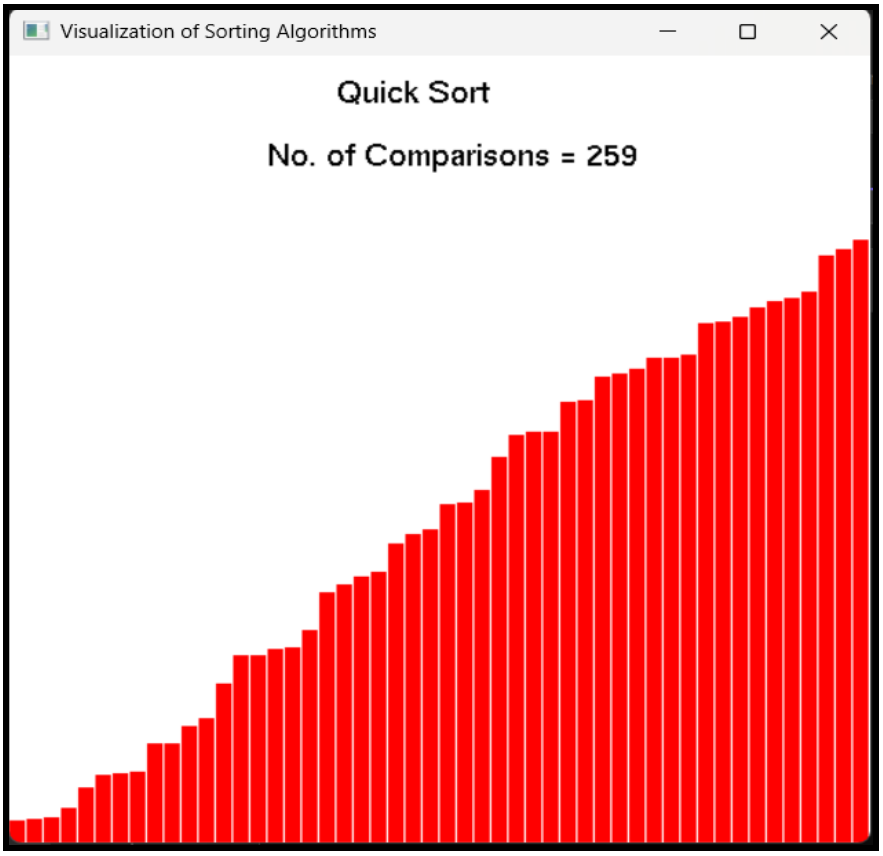
```
    sort_name = "Selection Sort";
    my_selsort.selectionsort(temp);
    Sleep(2000);

    temp = arr;
    BubbleSort my_bubsort;
    comparison_count = 0;
    sort_name = "Bubble Sort";
    my_bubsort.bubblesort(temp);
    Sleep(2000);

    temp = arr;
    MergeSort my_mergesort;
    comparison_count = 0;
    sort_name = "Merge Sort";
    my_mergesort.mergesort(temp, 0, temp.size() - 1);
    Sleep(2000);
}

// Main Function
int main(int argc, char** argv)
{
    srand(time(NULL));
    cout << "Generating random numbers\n";

    for (int i = 0; i < arr.size(); i++)
        arr[i] = rand() % 400;

    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_RGB | GLUT_SINGLE);
    glutInitWindowSize(width, height);
    glutCreateWindow("Visualization of Sorting Algorithms");
    glutDisplayFunc(display);
    init();
    gluOrtho2D(0, width, 0, height);
    glutMainLoop();
    return 0;
}
```

Output/Screenshots

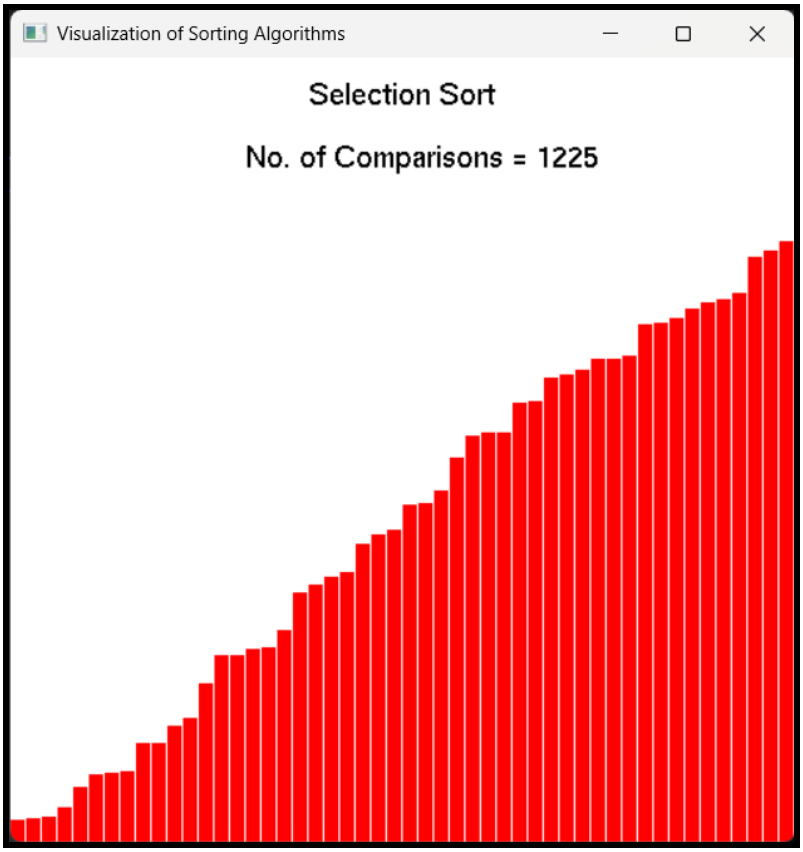
Generates Random Numbers:



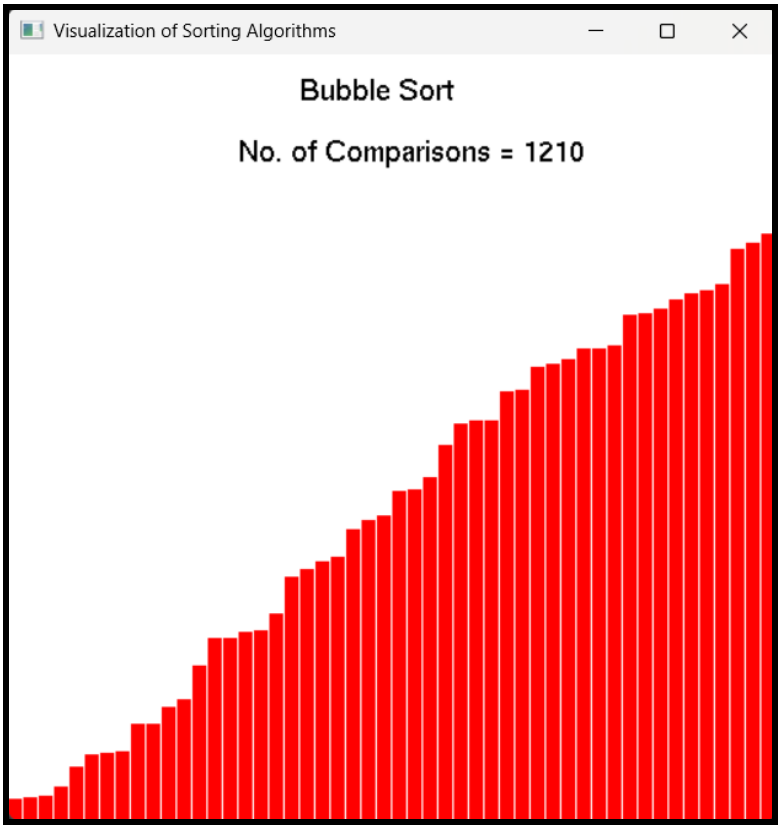
Quick Sort:



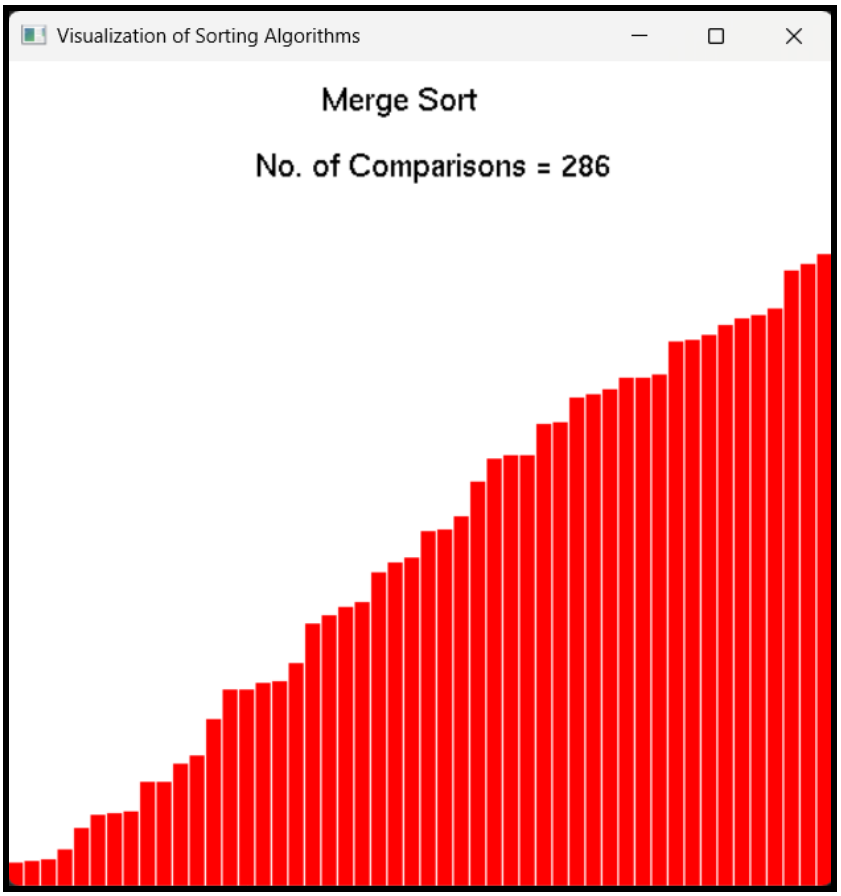
Selection Sort :


Visualization of Sorting Algorithms
Selection Sort
No. of Comparisons = 1225

Bubble Sort:


Visualization of Sorting Algorithms
Bubble Sort
No. of Comparisons = 1210

Merge Sort:


Visualization of Sorting Algorithms
Merge Sort
No. of Comparisons = 286