C++ Programming Work

Graph Coloring Algorithm Program Code Description

April 19, 2021

Jeremy J. Williams

1. Pseudocode

- Begin Program
- First it reads the XML graph file to get the Vertices and Edges and sets those vertices and edges ID number serially.
- Detects and sets total color by counting total vertices and then it sets Edges to a Graph list to find the Vertices color.
- Process first vertices and first color ID using its default value.
- Process rest of the vertices to color it by using Greedy Coloring algorithm.
- Finally, shows the Vertex coloring result.
- End Program

2. Source Code

2.1 Global Declarations

The following code are global declarations of headers, variables, and functions markers.

```
#include <iostream>
#include <fstream>
#include <string>
#include <vector>
#include <cstdlib>
#include <stdio.h>

using namespace std;

struct edge {
        string src;
        string dst;
};


// Function prototypes
string get_file(string fileName);
int get_vertices_edges(string xml, vector<string> &vertices, vector<edge> &edges);
int get_vertice_id(string vertice, vector <string> vertices);
string get_vertice_Name(size_t id, vector <string> vertices);
void greedyColoring(int maxnum, vector<int> &color, vector<vector<int>> graph);
```

2.2 Main

The following code is the main function for the entry point of the program.

The code starts the program and reads the XML file to process Greedy Color Graph.

```
int main()
{
        int n = 0;
        int e = 0;
        string fileName = "greedy_color_graph.xml";
        vector <string> vertices;
        vector <edge> edges;
        vector <vector<int>> graph;
        vector <int> color;
        string text = {};
        int nReply = 0;

        text = get_file(fileName);
        if (text == "")  goto CANCEL;

        nReply = get_vertices_edges(text, vertices, edges);
        if (nReply == -1) goto CANCEL;

        cout << "Total Number of Vertices: " << vertices.size() << endl;
        cout << "Total Number of Edges: " << edges.size() << endl;

        if (vertices.size() < 2) { cout << "Vertices must be more than one." << endl; goto CANCEL;
}
        if (edges.size() < 1) { cout << "Edges cannot be zero." << endl; goto CANCEL; }

        n = vertices.size();
        e = edges.size();
        graph.resize(n);
        color.resize(n);


        for (int i = 0; i < e; i++)
        {
                int x = get_vertice_id(edges[i].src, vertices);
                if (x == -1) { cout << "id not found of vertice " << edges[i].src << endl; goto
CANCEL; }
                int y = get_vertice_id(edges[i].dst, vertices);
                if (x == -1) { cout << "id not found of vertice " << edges[i].dst << endl; goto
CANCEL; }

                graph[x].push_back(y);
                graph[y].push_back(x);
        }

        for (size_t i = 0; i < graph.size(); i++)
        {
                for (size_t j = 0; j < graph[i].size(); j++)
                {
                  cout << "Vertex " << get_vertice_Name(i,vertices) << " or " << i << " is
                          connected with " << "Vertex " << get_vertice_Name(graph[i][j],vertices)
                         << " or " << graph[i][j] <<  endl;
                }
        }

        greedyColoring(n, color, graph);

        for (int i = 0; i<n; i++)
        {

                cout << "Vertex " << get_vertice_Name(i,vertices) << " is coloured " << color[i] +
                1 << "\n";
        }
CANCEL:
        system("PAUSE");
    return 0;
}
```

2.3 Greedy Coloring Process

The following code is for Greedy Coloring process.

It uses the minimum color for coloring the graph vertices.

```
void greedyColoring(int maxnum, vector<int> &color, vector<vector<int>> graph)
{
        int i = 0;
        size_t j = 0;
        int n = maxnum;
        bool* unused;
        unused = new bool[n];

        color[0] = 0;
        for (i = 1; i<n; i++)
                color[i] = -1;


        for (i = 0; i<n; i++)
                unused[i] = 0;

        for (i = 1; i < n; i++)
        {
                for (j = 0; j<graph[i].size(); j++)
                        if (color[graph[i][j]] != -1)
                                unused[color[graph[i][j]]] = true;
                int cr;
                for (cr = 0; cr<n; cr++)
                        if (unused[cr] == false)
                                break;

                color[i] = cr;

                for (j = 0; j<graph[i].size(); j++)
                        if (color[graph[i][j]] != -1)
                                unused[color[graph[i][j]]] = false;
        }

}
```

2.4 Vertex ID

The following code retrieves vertices ID from vertices list.

```
int get_vertice_id(string vertice, vector <string> vertices){

        for (size_t i = 0; i < vertices.size(); i++)
        {
                if (vertices[i] == vertice) return i;
        }
        return -1;
}
```

2.5 Vertex Name

The following code retrieves the vertices Name from vertices list.

```
string get_vertice_Name(size_t id, vector <string> vertices) {
        if (id < vertices.size()) return vertices[id];
        return "";
}
```

2.6 Vertex and Edge List

The following code retrieves vertices and edges list from XML text file.

```
int get_vertices_edges(string xml, vector<string> &vertices, vector<edge> &edges) {
        string tagGraph = "<graph>";
        string tagGraphEnd = "</graph>";
        string tagNodes = "<nodes>";
        string tagNodesEnd = "</nodes>";
        string tagNode = "<node";
        string Node = {};
        string Edge = {};
        string tagEdges = "<edges>";
        string tagEdgesEnd = "</edges>";
        string tagEdge = "<edge";
        string tagEnd = "/>";
        string atbName = "name=";
        string atbSrc = "src=";
        string atbDst = "dst=";
        string Src = {};
        string Dst = {};
        size_t nStart = 0;
        size_t nEnd = 0;
        size_t nOffset = 0;
        bool isValid = false;

        // scan for valid graph xml node
        isValid = false;
        nStart = xml.find(tagGraph);
        if (nStart != string::npos)
        {
                nStart = xml.find(tagGraphEnd, tagGraph.length());
                if (nStart != string::npos) isValid = true;
        }
        if (isValid == false)
        {
                cout << "Invalid graph xml node found." << endl;
                return -1;
        }

        // scan for valid nodes xml node
        isValid = false;
        nStart = xml.find(tagNodes);
        if (nStart != string::npos)
        {
                nStart = xml.find(tagNodesEnd, tagNodes.length());
                if (nStart != string::npos) isValid = true;
        }
        if (isValid == false)
        {
                cout << "Invalid nodes xml node found." << endl;
                return -1;
        }

        // scan for valid edges xml node
        isValid = false;
        nStart = xml.find(tagEdges);
        if (nStart != string::npos)
        {
                nStart = xml.find(tagEdgesEnd, tagEdges.length());
                if (nStart != string::npos) isValid = true;
        }
        if (isValid == false)
        {
                cout << "Invalid edges xml node found." << endl;
                return -1;
        }

        // find Nodes
        nStart = xml.find(tagGraph);
        if (nStart != string::npos)
        {
                nOffset = tagGraph.length();
                nStart = xml.find(tagNodes, nOffset);
                if (nStart != string::npos)
        {
                nOffset = nStart + tagNodes.length();
                nStart = xml.find(tagNode, nOffset);
                while (nStart != string::npos)
                {
                        nOffset = nStart + tagNode.length();
                        nStart = xml.find(atbName, nOffset);
                        if (nStart != string::npos)
                        {
                                nOffset = nStart + atbName.length();
                                nEnd = xml.find(tagEnd, nOffset);
                                if (nEnd != string::npos)
                                {
                                        Node = xml.substr(nOffset, nEnd - nOffset);
                                        Node = Node.substr(1, Node.length() - 2);
                                        vertices.push_back(Node);
                                        cout << "Vertex " << Node << " is " <<
                                        get_vertice_id(Node, vertices) << endl;
                                        nOffset = nEnd + tagEnd.length();
                                        nStart = xml.find(tagNode, nOffset);
                                }
                                else
                                {
                                        cout << "Invalid end of node." << endl;
                                        return -1;
                                }

                        }
                        else
                        {
                                cout << "Attribute 'Name' not found." << endl;
                                return -1;
                        }
                }
        }
}

// find Edges
nStart = xml.find(tagGraph);
if (nStart != string::npos)
{
        nOffset = tagGraph.length();
        nStart = xml.find(tagEdges, nOffset);
        if (nStart != string::npos)
        {
                nOffset = nStart + tagEdges.length();
                nStart = xml.find(tagEdge, nOffset);
                while (nStart != string::npos)
                {
                        nOffset = nStart + tagEdge.length();
                        nStart = xml.find(atbSrc, nOffset);
                        if (nStart != string::npos)
                        {
                                nOffset = nStart + atbSrc.length();
                                nEnd = xml.find(atbDst, nOffset);
                                if (nEnd != string::npos)
                                {
                                        Src = xml.substr(nOffset, nEnd - nOffset);
                                        Src = Src.substr(1, Src.length() - 3);
                                        //cout << "edge source " << Src << endl;
                                        nStart = nEnd;
                                        nOffset = nEnd + atbDst.length();
                                        nEnd = xml.find(tagEnd, nOffset);
                                        if (nEnd != string::npos)
                                        {
                                                Dst = xml.substr(nOffset, nEnd - nOffset);
                                                Dst = Dst.substr(1, Dst.length() - 3);
                                                //cout << "edge destination " << Dst << endl;
                                        }
                                        else
                                        {
                                                cout << "Invalid end of edge node." << endl;
                                                return -1;
                                        }
                                        edge e;
                                        e.src = Src; e.dst = Dst;
                                        edges.push_back(e);
                                        cout << "Edge " << Src << "--" << Dst << endl;
```

```
                                                        nOffset = nEnd + tagEnd.length();
                                                        nStart = xml.find(tagEdge, nOffset);
                                                }
                                                else
                                                {
                                                        cout << "Invalid end of attribute 'Dst'." << endl;
                                                        return -1;
                                                }

                                        }
                                        else
                                        {
                                                cout << "Attribute 'Src' not found." << endl;
                                                return -1;
                                        }
                                }
                        }
                }

        return 0;
}
```

2.6 XML Data

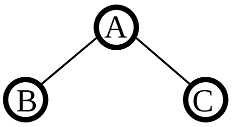
The following code read all XML text from the XML file.

```
string get_file(string fileName)
{
        string buffer;
        char c;

        ifstream in(fileName);   if (!in) { cout << fileName << " not found \n";
}
        while (in.get(c)) buffer += c;
        in.close();

        return buffer;
```

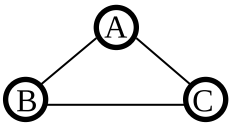
3. Execution of Source Code

See execution screenshots using the following sample graphs:

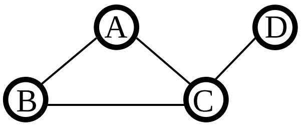
Sample 1)



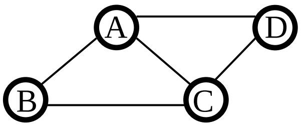
Sample 2)



Sample 3)

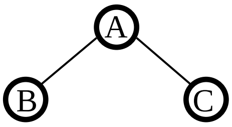


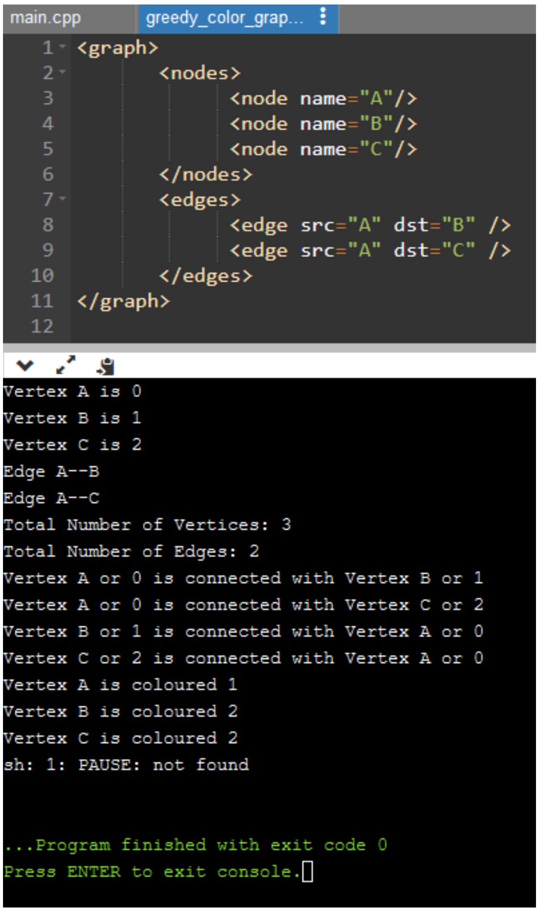
Sample 4)



3.1 Execution #1

Sample 1)



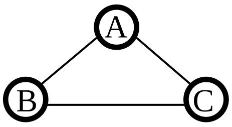


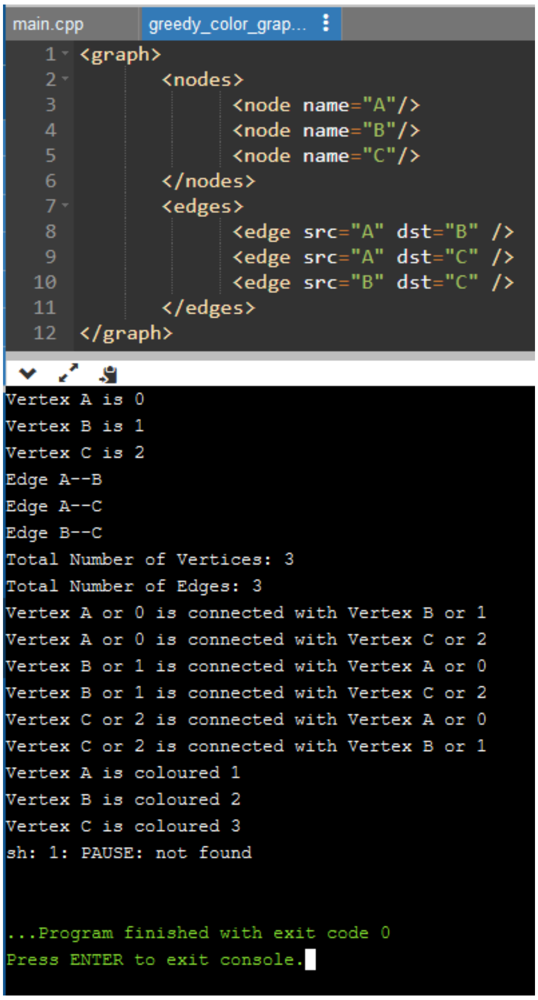
```xml
<graph>
	<nodes>
		<node name="A"/>
		<node name="B"/>
		<node name="C"/>
	</nodes>
	<edges>
		<edge src="A" dst="B" />
		<edge src="A" dst="C" />
	</edges>
</graph>

```

```
Vertex A is 0
Vertex B is 1
Vertex C is 2
Edge A--B
Edge A--C
Total Number of Vertices: 3
Total Number of Edges: 2
Vertex A or 0 is connected with Vertex B or 1
Vertex A or 0 is connected with Vertex C or 2
Vertex B or 1 is connected with Vertex A or 0
Vertex C or 2 is connected with Vertex A or 0
Vertex A is coloured 1
Vertex B is coloured 2
Vertex C is coloured 2
sh: 1: PAUSE: not found


...Program finished with exit code 0
Press ENTER to exit console.
```

3.2 Execution #2

Sample 2)



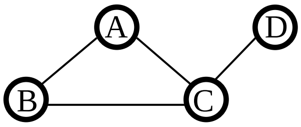


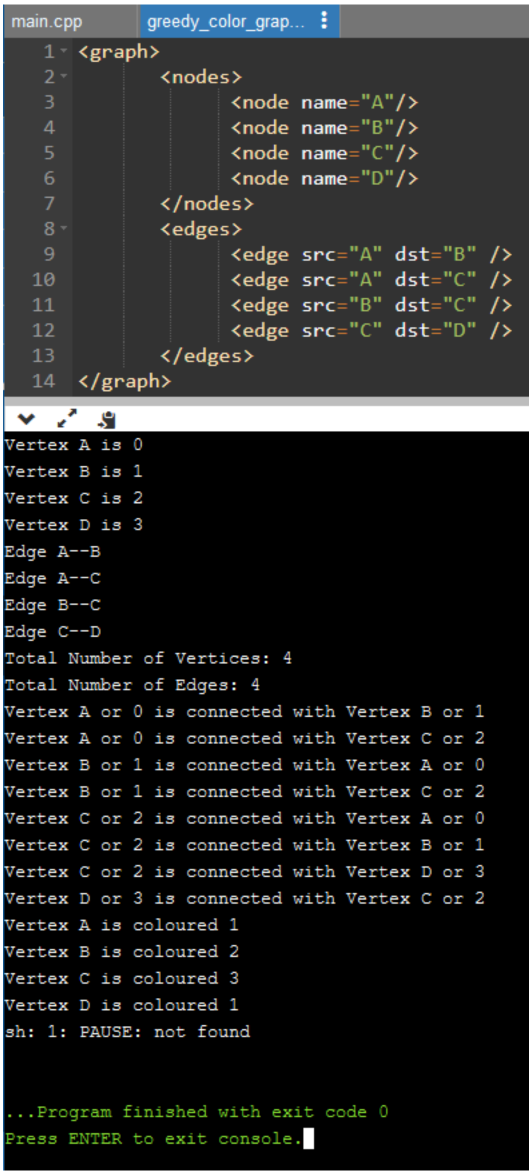
```
<graph>
       <nodes>
             <node name="A"/>
             <node name="B"/>
             <node name="C"/>
       </nodes>
       <edges>
             <edge src="A" dst="B" />
             <edge src="A" dst="C" />
             <edge src="B" dst="C" />
       </edges>
</graph>
```

```
Vertex A is 0
Vertex B is 1
Vertex C is 2
Edge A--B
Edge A--C
Edge B--C
Total Number of Vertices: 3
Total Number of Edges: 3
Vertex A or 0 is connected with Vertex B or 1
Vertex A or 0 is connected with Vertex C or 2
Vertex B or 1 is connected with Vertex A or 0
Vertex B or 1 is connected with Vertex C or 2
Vertex C or 2 is connected with Vertex A or 0
Vertex C or 2 is connected with Vertex B or 1
Vertex A is coloured 1
Vertex B is coloured 2
Vertex C is coloured 3
sh: 1: PAUSE: not found


...Program finished with exit code 0
Press ENTER to exit console.
```

3.3 Execution #3

Sample 3)



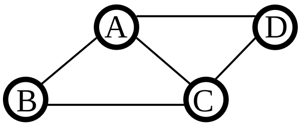


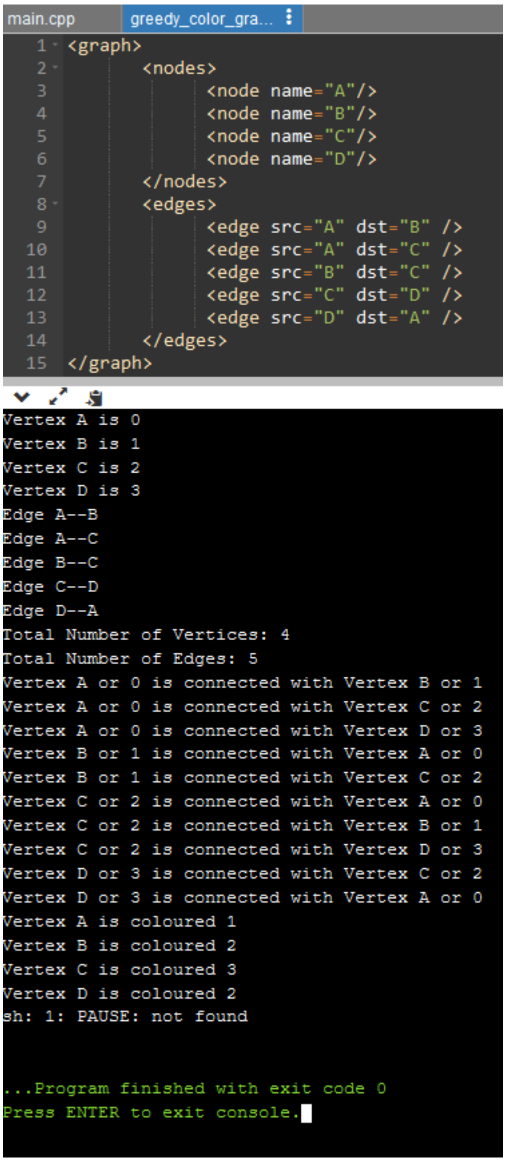
```
<graph>
        <nodes>
                <node name="A"/>
                <node name="B"/>
                <node name="C"/>
                <node name="D"/>
        </nodes>
        <edges>
                <edge src="A" dst="B" />
                <edge src="A" dst="C" />
                <edge src="B" dst="C" />
                <edge src="C" dst="D" />
        </edges>
</graph>
```

```
Vertex A is 0
Vertex B is 1
Vertex C is 2
Vertex D is 3
Edge A--B
Edge A--C
Edge B--C
Edge C--D
Total Number of Vertices: 4
Total Number of Edges: 4
Vertex A or 0 is connected with Vertex B or 1
Vertex A or 0 is connected with Vertex C or 2
Vertex B or 1 is connected with Vertex A or 0
Vertex B or 1 is connected with Vertex C or 2
Vertex C or 2 is connected with Vertex A or 0
Vertex C or 2 is connected with Vertex B or 1
Vertex C or 2 is connected with Vertex D or 3
Vertex D or 3 is connected with Vertex C or 2
Vertex A is coloured 1
Vertex B is coloured 2
Vertex C is coloured 3
Vertex D is coloured 1
sh: 1: PAUSE: not found


...Program finished with exit code 0
Press ENTER to exit console.
```

3.4 Execution #4

Sample 4)





```
<graph>
        <nodes>
                <node name="A"/>
                <node name="B"/>
                <node name="C"/>
                <node name="D"/>
        </nodes>
        <edges>
                <edge src="A" dst="B" />
                <edge src="A" dst="C" />
                <edge src="B" dst="C" />
                <edge src="C" dst="D" />
                <edge src="D" dst="A" />
        </edges>
</graph>
```

```
Vertex A is 0
Vertex B is 1
Vertex C is 2
Vertex D is 3
Edge A--B
Edge A--C
Edge B--C
Edge C--D
Edge D--A
Total Number of Vertices: 4
Total Number of Edges: 5
Vertex A or 0 is connected with Vertex B or 1
Vertex A or 0 is connected with Vertex C or 2
Vertex A or 0 is connected with Vertex D or 3
Vertex B or 1 is connected with Vertex A or 0
Vertex B or 1 is connected with Vertex C or 2
Vertex C or 2 is connected with Vertex A or 0
Vertex C or 2 is connected with Vertex B or 1
Vertex C or 2 is connected with Vertex D or 3
Vertex D or 3 is connected with Vertex C or 2
Vertex D or 3 is connected with Vertex A or 0
Vertex A is coloured 1
Vertex B is coloured 2
Vertex C is coloured 3
Vertex D is coloured 2
sh: 1: PAUSE: not found


...Program finished with exit code 0
Press ENTER to exit console.
```

References

[1] **Wikipedia contributors**. "Greedy coloring." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 7 Aug. 2020. Web. 18 Apr. 2021

[2] **Sanfoundry.com**, C++ Program to Perform Greedy Coloring, https://www.sanfoundry.com/cpp-program-perform-greedy-coloring/, Web. 18 Apr. 2021

[3] **GeeksforGeeks.org**, Graph Coloring - Set 2 (Greedy Algorithm), https://www.geeksforgeeks.org/graph-coloring-set-2-greedy-algorithm/, Web. 18 Apr. 2021

[4] **OpenGenus IQ.org**, Graph Coloring Greedy Algorithm [O(V^2 + E) time complexity], https://iq.opengenus.org/graph-colouring-greedy-algorithm/, Web. 18 Apr. 2021

[4] **Brilliant.org**, Greedy Algorithms, https://iq.opengenus.org/graph-colouring-greedy-algorithm/, Web. 18 Apr. 2021

[5] **Wikipedia contributors**. "Greedy algorithm." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 18 Mar. 2021. Web. 18 Apr. 2021.

[6] **Encyclopedia of Mathematics**. Greedy algorithm. https://encyclopediaofmath.org/index.php?title=Greedy_algorithm, Web. 18 Apr. 2021.

[7] **OnlineGDB.com**, Online_C++_compiler, https://www.onlinegdb.com/online_c++_compiler, Web. 18 Apr. 2021.

[8] **Github.com**, Research-Programming-Work, https://github.com/jeremyjwsc/Research-Programming-Work, Web. 18 Apr. 2021.