An Efficient Stack Based Graph Traversal Method for Network Configuration

Prajwala. N. B, Vijayalakshmi. M. K

Abstract*: The research focuses on the efficient approach to find out the connectivity between nodes and provides the list of networks of the network if available. Networks can be logically represented as a graph; graph traversal is one of the common mechanisms in the network to find the connectivity and subnetworks. In this proposed approach stacks are used to find a number of connected components. The number of resultant stacks is a metric for measurement of components. The proposed algorithm is efficient compared to graph traversal techniques like BFS and DFS as its order of complexity is O(n2). Finding a number of components can be useful to find connectivity in networks to check reachability in the network, connectivity in any electronic circuits and island and so on. The graph can be represented by adjacency matrix or incidence matrix. If there is an edge between two vertices then it is represented by 1 and 0 otherwise. Incidence matrix is an n*m matrix where n is a number of vertices and m is a number of edges, where rows represent vertices and column represents edges. If two vertices are connected by an edge then it is represented by 1 and 0 otherwise.

***Index Terms*: Adjacency Matrix, Graph; Networks of Network, Stack, VBS.**

I. INTRODUCTION

A graph is said to have a component if every node has a path from every other node. For this paper here only unidirectional and non-weighted graphs are considered. There are already some methods to extract components in a graph, like a depth-first search, branch and bound methods. In this paper, stacks are used to find a number of components.

Graphs are represented as adjacency matrix; by using adjacency matrix individual components are extracted. In an undirected graph, a vertex 'v' is reachable from a vertex 'u' if there is a path from 'u' to 'v'. Reachability is an equivalence relation since it is reflexive, symmetric and transitive. This method is tested for dif-ferent types of graphs but this requires a basic condition that the sum of degrees of all vertices should be even and also this doesn't work for trees. The tree is a graph in which any two vertices are connected by an exactly one single path. Also, the tree is defined as an acyclic connected graphIn order to find the number of components, stacks are used. A stack is an abstract data structure which serves as a collection of similar elements with principles like first in last out or last in first out. Push is an operation to add or insert an element from the top of the stack whereas pop is an operation to delete or remove an element from the top of the stack. The element which is inserted first will be in the rare end of the stack and the element which is inserted last will be in the top of the stack. Size of the stack can be found by stack [top]-stack [rare]. A number of stacks at the end are nothing but a number of components in a graph. There are different types of graphs in graph theory. This metho-dology works well for graphs with bridges, self-loops, cyclic and acyclic graphs and isomorphic graphs. But here the main constraint is that the vertices in individual components should be named in such a way that all vertices are traversable without repeating edges. The size of each stack gives the total number of vertices in a component and the number of resultant stacks gives the total number of components.

II. APPLICATION OF GRAPH THEORY IN VARIOUS FIELDS

Knowingly or unknowingly graph theory is used in all branches of Science. Similarly, the idea of finding a number of components in a given graph also helps in various branches of science like Physics, Chemistry, Biology, and many more fields. The main application is to check the connections or reachability. This concept is also used in solving problems like traveling salesman problem [1], postman problem, and some similar problems. Graph theory is used mostly in Physics [2] for circuit connections. The connection of battery, voltmeter, ammeter, resistance using wires can be done by using the concept of graph theory. The idea of finding the number of components in the given graph helps to check the connectivity of the circuits. The application of graph theory to the network has a real-time advantage. This idea of finding the number of components in the given graph also helps in a network of telephone connections, Google maps [3], railroads, highways, pipelines of gas and water and so on to know the connectivity. By knowing the number of components of the graph, the network connection, as well as dis-connection, can be identified. Finding connected components in network help for better data aggregation and to find optimal route to transfer data[12][13]. Graph theory is also used in the Electrical network, which is the collection of interconnected electrical devices like capacitors, batteries, resistors, and switches.

Revised Manuscript Received on June 07, 2019.

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After finding the number of components using this algorithm, the connectivity and disconnectivity in the network can be found. Graph theory is also widely used in the field of Chemistry [4]. Graph theory is used to represent structural formulae of chemicals, where a number of vertices represent the atoms and number of edges represents the bonds. Graph theory finds its application in cluster computing in order to calculate the interconnection and network utilization be-tween cluster components also it helps in creating logs for schedu-lers for monitoring performance[11]. In RREQ Protocol, Path optimization is done using the graph technique in the wireless sensor network to send the information from source to sink. This protocol helps to achieve the load balancing in the WSN[12][13]. In MVBS protocol modified CDS is used to generate the backbone network with the help of graph and sub graph, in this graph is con-sidered as the wireless sensor network and sub graph is considered as the backbone network. This protocol increases the lifetime of WSN[13].

III. RESEARCH METHODOLOGY

The minimum number of networks of network is one and a maximum number of networks of network may be n, where n represents the number of nodes and indicates that all nodes are isolated. The graph is represented using adjacency matrix a[n,n], where n is a number of vertex and size of the matrix. The different vertex that is, indices are represented as V1, V2… Vn and stacks are represented as S1, S2…Sn.

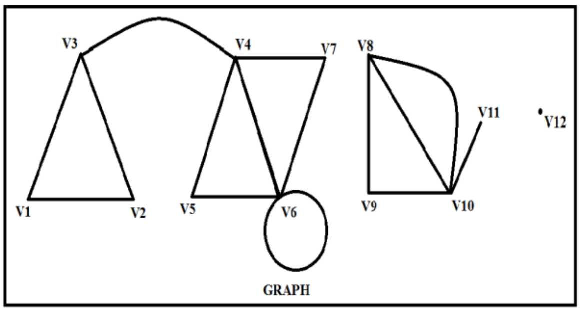

Fig – 1: Graph with three components (G1)

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
V1	0	1	1	0	0	0	0	0	0	0	0	0
V2	1	0	1	0	0	0	0	0	0	0	0	0
V3	1	1	0	1	0	0	0	0	0	0	0	0
V4	0	0	1	0	1	1	1	0	0	0	0	0
V5	0	0	0	1	0	1	0	0	0	0	0	0
V6	0	0	0	1	1	2	1	0	0	0	0	0
V7	0	0	0	1	0	1	0	0	0	0	0	0
V8	0	0	0	0	0	0	0	0	1	2	0	0
V9	0	0	0	0	0	0	0	1	0	1	0	0
V10	0	0	0	0	0	0	0	2	1	0	1	0
V11	0	0	0	0	0	0	0	0	0	1	0	0
V12	0	0	0	0	0	0	0	0	0	0	0	0

Fig - 2: Adjacency matrix a[12, 12]

In this methodology, only undirected graphs are considered so the adjacency matrix is always a symmetric matrix with its diagonal elements equal to zero or two. The traversal can be checked only for elements above diagonal or for the elements below the diagonal. Traversal always starts from a[i][i+1].

The traversal starts from first-row second column element of the matrix, that is from a[V1][V2] the element at a[V1][V2] is 1 that indicates there is a path from V1 to V2. V1 and V2 are pushed on to stack. V2 will be at the top of the stack S1. The next traversal starts from top element of the stack that is V2. The element at a[V2][V3] is 1 hence V3 is pushed on to the stack. The process continues until further traversal is not possible or all the vertices are covered. If further traversal is not possible and all vertices are not covered then a new stack is created and the vertex is pushed on to the stack. In this example from V7 traversal is not possible and vertices V8, V9, V10, V11, and V12 are remaining so the traversal starts from V8. V8 is pushed to new stack S2. From V8 the possible traversal is V9 hence V9 is pushed on to the stack. The traversal starts from top element of the stack that is V9. The traversal continues until all vertices till V11 are pushed on to the stack S2, so S2 has elements V8, V9, V10, V11. The traversal cannot be continued but the vertex V12 is still remaining, hence the traversal starts from V12, V12 is pushed on to the new stack S3. No more traversal is possible from the vertex V12, vertex V12 considered as an isolated vertex. The number of the stack at the end of traversal gives the number of components in the graph and the size of each stack gives the number of vertices in each component, here S3 has one element that indicates V12 is an isolated vertex.

Stack S1: First stack with 7 vertices.

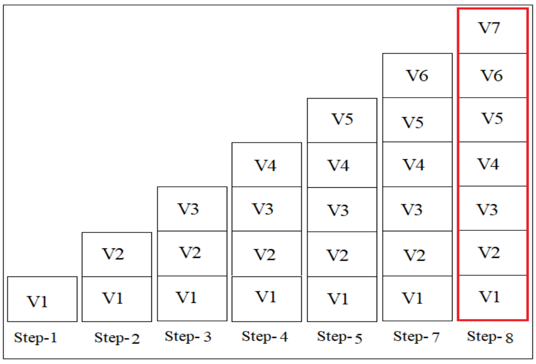

Fig - 3: Stack S1 for the first component

Stack S2: Second stack with 4 vertices.

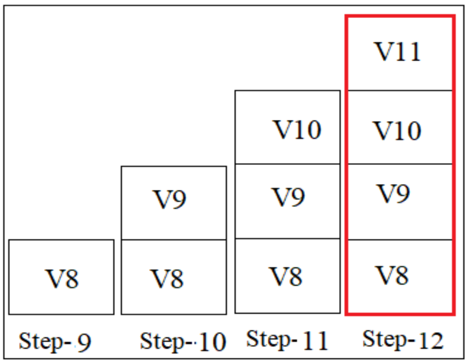

Fig -4: Stack S2 for the second component

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Stack S3: Third stack with 1 vertex.

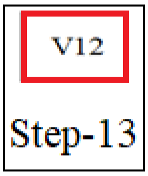


Fig -5: Stack S3 for the third component.

Three stacks are produced for this graph. That shows there are three components in the graph. The size of the first stack is seven that means the first component has seven vertices V1, V2, V3, V4, V5, V6, and V7. The size of the second matrix is four that indicates the second component has four vertices that are V8, V9, V10, and V11. And the size of the third matrix is one that indicates that the third component has one vertex V12.

This method works well for graphs with ordered vertices, graphs with isolated vertices and graph with maximum of one pendant vertex for a component. The ordering of vertices means that all vertices are traversable starting from one vertex without repeating any vertices.

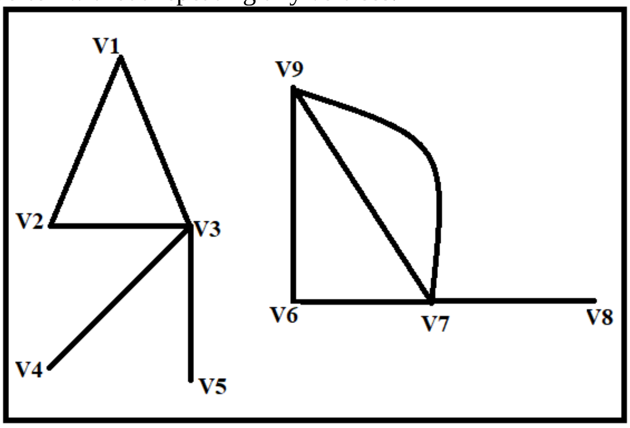
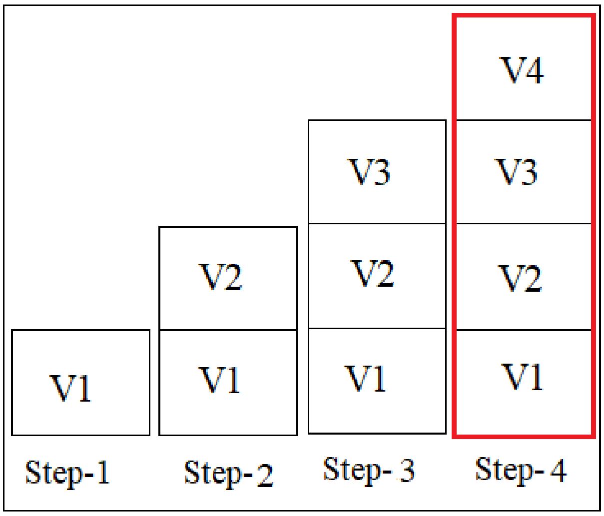


Fig - 6: Graph with changed vertex order and three pendant vertices

	V1	V2	V3	V4	V5	V6	V7	V8	V9
V1	0	1	1	0	0	0	0	0	0
V2	1	0	1	0	0	0	0	0	0
V3	1	1	0	1	1	0	0	0	0
V4	0	0	1	0	0	0	0	0	0
V5	0	0	1	0	0	0	0	0	0
V6	0	0	0	0	0	0	1	0	1
V7	0	0	0	0	0	1	0	1	2
V8	0	0	0	0	0	0	1	0	0
V9	0	0	0	0	0	1	2	0	0

Fig - 7: Adjacency matrix a[9,9].



Stack S1.

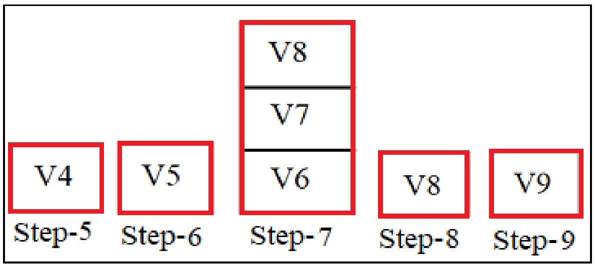


Fig -8: Stack of the above graph.

The order of the vertices of the graph is changed as shown in fig-4 and there are three pendant vertices. The adjacency matrix for fig-4 will be as shown in fig-5. The traversal starts from V1. The element at a[V1][V2] is one hence the vertices V1 and V2 are pushed on to the stack S1. The next traversal starts from V2. The element at a[V2][V3] is 1 hence V3 is pushed on to the stack. The element at a[V3][V4] is 1 and hence V4 is pushed on to the stack. Further traversal from V4 is not possible and this ends up with the first stack, but the vertices V5 of the first component is not pushed on to the stack S1. The traversal starts from V4, V4 is pushed on to new stack S2, further traversal from V4 is not possible because there is no path from V4. Stack S2 has only one element that indicates it is an isolated vertex but V4 is a pendant vertex. Then the traversal gets incremented and starts from V5, vertex V5 is pushed to stack S3. Further traversal from V5 is not possible and V5 forms a separate stack S3 which again indicates V5 as an isolated vertex. Then the traversal starts from V6 and pushes V6, V7, and V8 to stack S4, V8 is on the top of the stack S4 but further traversal from V8 is not possible. The traversal again starts from V8, V8 is pushed on to the new stack S5. Now the top element of S5 is V8 further traversal is not possible but the vertex V9 is still remaining. The traversal from V9 is initiated and V9 gets pushed on to the new stack S6. These graph traversal results in six stacks S1 with four vertices, S2 with one vertex, S3 with one vertex, S4 with three vertices, S5 with one vertex and S6 with one vertex.

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The result indicates that there are 6 components in the graph with four isolated vertex which is wrong. So the ordering of the graph and pendant vertices not more than 1 for a component is important in this algorithm. The proposed algorithm is implemented to check the connectivity between all nodes, between sub-networks and individual network infrastructure. This can be further used in electronics to find a number of circuits, also useful in designing layouts for water connections and electric connections

IV. ALGORITHM

Input: n-number of nodes, adjacency matrix a[n][n].

Output: S1, S2… Sm, that is m number of stacks, k1, k2… km that is the size of each stack.

```
push(V): Sm[top]==V
   top++;
1: a[n][n] input.
2: m=1, p=0
3: top= -1
4: push (V1) to stack S1
5: for i=1 to (n-1)
6: for j=(i+1) to (n-1)
7: if a[i][j]==1
8: push Vj to stack Sm
9: i=j
10: end if
11: else
12: if ((a[i][n]==0)&&(i<n))
13: p=top
14: (p+1) number of vertices in a component.
15: m++
16: top= -1
17: push (V(i+1)) to stack Sm
18: go to step-4
19: end for
20: m number of components.
```

V. TIME COMPLEXITY

The time complexity for this algorithm directly depends on the number of vertices in a graph as the number of vertices increases the time complexity also increases. If there are n isolated vertices in a graph then n stacks are generated.

The time complexity of this algorithm is (n/2)(n2-n+1). Time com-plexity always depends on the number of vertices in a graph. The complexity of this algorithm is Θ(n3/2).

T α (n/2)(n2-n+1)

Fig-9: Time versus a number of vertices.

	n=1	n=2	n=3	n=4	n=5
T	0.5	3	10.5	26	52.5

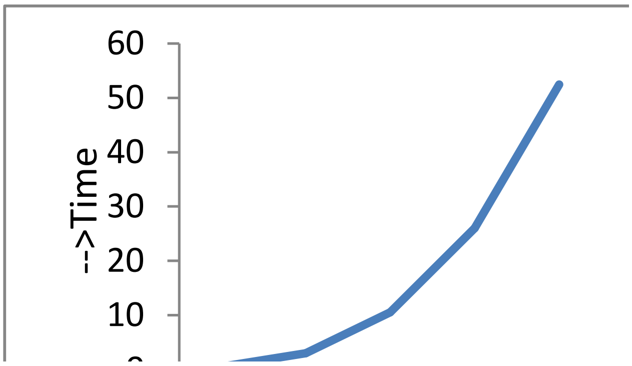

Fig-10: Graph for time versus number of vertices

VI. CONCLUSION

This algorithm performance is efficient with parallel communication links between the nodes, self-path, bridges and isolated nodes. But requires nodes to be in order according to the physical or logical address and it should be in the form of the adjacency matrix. It efficiently gives the number of networks of network and listing the number of nodes of each network.

APPLICATIONS

This can be implemented in maps, electricity connection, networks to find a number of connected components and disconnected com-ponents.

This algorithm can be extended to work for graphs with more than one pendant vertices and tree.

ACKNOWLEDGEMENT

Wholeheartedly, I thank Mr.Santosh Anand and Mr. Manishankar for supporting us in all aspects to publish this paper, providing encouragement and for extending the support possible at each stage of the paper.

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