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A Scientific Research Analysis to Identify Number of Components in a Graph

Prajwala.N.B, Indumathi.S.M.

***Abstract:** In this work a method to find number of components, possible connection and not possible connection between nodes in a graph are proposed. Graphs are represented as adjacency matrix. The elements of adjacency matrix can be any integer, 0 represents that there is no edge between vertices, any integer greater than 0 indicates that there are 1 or more edges between nodes, 2 in diagonal if the vertices have self-loops. The sum of any rows or columns gives the degree of the vertex. If the sum is zero that indicates that the vertex is isolated vertex, isolated vertex also forms a component. The point of disconnectivity in the graph is identified from the adjacency matrix, the total number of components will be summation of isolated vertices, number of disconnectivity pattern +1. Some observations on adjacency matrix are made to find point of disconnectivity and number of components in a graph.*

***Keywords:** Adjacency matrix, Components, Connectivity, Disconnectivity, Point of disconnectivity.*

I. INTRODUCTION

In any graph there may be connected components or disconnected components. Connected components are those in which every vertex is reachable from any other vertices. Some observations are made on adjacency matrix to find number of components in a graph. In a given graph if all vertices are connected that is all vertices are reachable from any other vertices then thegraph will have one component. If all vertices in a graph are not connected that is no edges between any vertices then there will be n number of components, where n is number of vertices.

Adjacency matrix a[n,n] is used to represent graph, it is a symmetric square matrix with n rows and n columns, where n represents number of vertices in a graph. If there is no edge between any two vertices then it is represented by 0 and any other integer based on the number of edges between vertices. Thisapproach gives the point of disconnectivity between components. The degree of any vertex can also be found from adjacency matrix, the sum of any row or column gives the degree of respective vertex. The minimum number of components that can be there in any graph is one and the maximum number of componentswould be n, where n is number of vertices in a graph. If a graph has n components, which means all vertices are disconnected and the number of edges between nodes will be zero in the graph, but there may be self-loops for vertices.

The adjacency matrix gives connection possible matrix that is possible reachability that can be there between any vertices. The connection not possible matrix can also be determined from adjacency matrix itself. Connection not possible matrix isto show that there cannot be direct edge between vertices.

II. RELATED WORK

[1]Author represented the cited article in the form of graph, where nodes represent the author and the edge represents the citation. The direction of the edge indicates weather the author have cited another author paper. if there are no edges to a node that is isolated vertices indicates that the authors article is not cited and author has not cited any article, also the number of components gives the total number of authors considered for citation graph of computer science literature. Here in degree gives total number of authors cited the article and out degree gives the number of articles cited by the author. Within a component there may be strong connection or weak connection.Between components there is no connectivity. Isolated components are independent component that is they are not at all connected. In any component if there are bridges then they are weakly connected.[2]Adjacency matrix is a symmetric matrix whichare used to represent undirected graphs where aij=aji. From adjacency matrix the vertices which are connected can be determined. The not allowed connection matrix can be constructed from adjacency matrix. From this the vertices which are not connected strongly or weakly without altering the graph architecture can be extracted. [3] In a graph one node is connected toanother node,when complement is considered for the same graph,the connected nodes become disconnected. [4] A simple graph having G= (V, E) of a molecular graph is represented by n = |V| nodes and m = |E| edges, where non-hydrogen atoms arerepresented by nodes vi€V and covalent bonds between the analogous atoms are represented by edges (ei,ej) € E. Carbon skeleton of the moleculescan be represented as molecular graphs.[5]Author implemented the path generation and path optimization algorithm using graph to improve the lifetime of wireless sensor network in this work, author consider vertex as node and list all the possible paths from each vertex to the destination (vertex). [6] Author implements the load balancing in the wireless sensor network. In thiswork implemented path creation and utilization in such a way that all nodes (vertices) are participation equally and effectively for communication.

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* Correspondence Author
Prajwala.N.B*, Department of Computer Science, Amrita School of Arts &Sciences,Mysuru, Amrita VishwaVidyapeetham, India.
Indumathi.S.M*, Department of Computer Science, Amrita School of Arts &Sciences,Mysuru, Amrita VishwaVidyapeetham, India.

[7] Author designed the real time SoC which can help soldier to communication to the control room/nearby soldier.In this work, author implemented the protocol for Soc.

Finding number of component is useful to find number of autonomous systems in networks. Alsouseful in finding molecular structures of molecules in chemistry, can also be used to find number of circuits are isolated circuits in electrical components and also in GPS are google maps, traffic lights, designing layouts which includes water supply and electricity connection for every house. This can be helpful for solving travelling sells men and post man problem.

III. RESEARCH METHODOLOGY

3. 1. Algorithm to find number of components in a graph:

This algorithm works well for undirected graph with trees, loops, bridges, isolated vertex. But it requiresnaming of the vertices to be in sequence within the component and the isolated vertex should be given last number. For this algorithm adjacency matrix is considered since adjacency matrix is symmetric in nature. If V1, V2…Vn are n number of nodes and edges are connection between nodes. Figure-1 represents connection allowed graph. Which means that the node Vi and Vj can communicate directly or through another node if there is an edge between them where i and j are any integers between 1 to n.

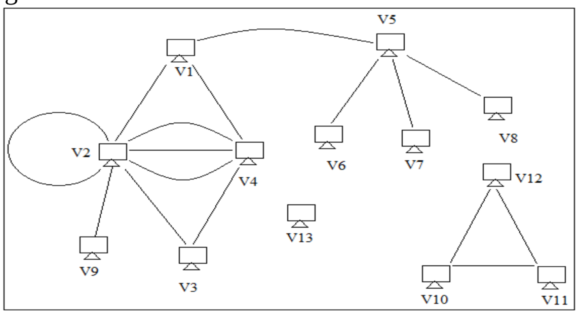

Figure-1 Graph with three components

The graph in figure-1 has three components, first component with self loop, bridge and tree, second component is a complete graph with three vertices and third component is an isolated vertex. Figure 2 shows the adjacency matrix for the graph in figure-1.The isolated verticies form a component, for an isolated vertex the degree is zero. The sum of each rows or columns gives the degree of the vertex, which indicates the load on nodes in network.The total number of isolated vertices c is found from the adjacency matrix, that is total number of zeros after adding rows or columns as indicated in figure-2.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	DEGREE
V1	0	1	0	1	1	0	0	0	0	0	0	0	0	3
V2	1	2	1	3	0	0	0	0	1	0	0	0	0	8
V3	0	1	0	1	0	0	0	0	0	0	0	0	0	2
V4	1	3	1	0	0	0	0	0	0	0	0	0	0	5
V5	1	0	0	0	0	1	1	1	0	0	0	0	0	4
V6	0	0	0	0	1	0	0	0	0	0	0	0	0	1
V7	0	0	0	0	1	0	0	0	0	0	0	0	0	1
V8	0	0	0	0	1	0	0	0	0	0	0	0	0	1
V9	0	1	0	0	0	0	0	0	0	0	0	0	0	1
V10	0	0	0	0	0	0	0	0	0	0	1	1	0	2
V11	0	0	0	0	0	0	0	0	0	1	0	1	0	2
V12	0	0	0	0	0	0	0	0	0	1	1	0	0	2
V13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	8	2	5	4	1	1	1	1	2	2	2	0	c=1

Isolated Vertex

Figure-2 Adjacency matrix a[13,13]

Figure-2 is an adjacency matrix a[13][13] with one isolated vertex V13 which is marked in blue. The degree of which is zero, that is the sum of V13 row and V13 column is zero.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
V1	0	1	0	1	1	0	0	0	0	0	0	0	0
V2	1	2	1	3	0	0	0	0	1	0	0	0	0
V3	0	1	0	1	0	0	0	0	0	0	0	0	0
V4	1	3	1	0	0	0	0	0	0	0	0	0	0
V5	1	0	0	0	0	1	1	1	0	0	0	0	0
V6	0	0	0	0	1	0	0	0	0	0	0	0	0
V7	0	0	0	0	1	0	0	0	0	0	0	0	0
V8	0	0	0	0	1	0	0	0	0	0	0	0	0
V9	0	1	0	0	0	0	0	0	0	0	0	0	0
V10	0	0	0	0	0	0	0	0	0	0	1	1	0
V11	0	0	0	0	0	0	0	0	0	1	0	1	0
V12	0	0	0	0	0	0	0	0	0	1	1	0	0
V13	0	0	0	0	0	0	0	0	0	0	0	0	0

Pattern p

Figure-3 Adjacency matrix a[13,13]

The green mark in figure-3 represents the pattern p, which is point of disconnectivity for the components. The number of components can be found by c+p+1. Where c represents number of isolated vertices and p represents number of components.

The adjacency matrix is searched for the pattern p if the pattern is found then the number of components will be p+1. The total number of components in a graph will be c+p+1.

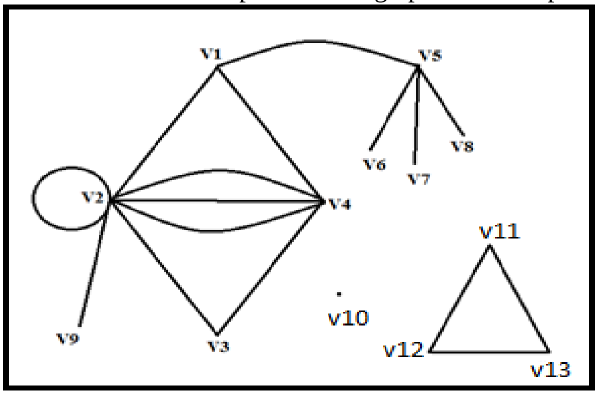

Figure-4 Graph with isolated vertex order changed.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	Degree
V1	0	1	0	1	1	0	0	0	0	0	0	0	0	3
V2	1	2	1	3	0	0	0	0	1	0	0	0	0	8
V3	0	1	0	1	0	0	0	0	0	0	0	0	0	2
V4	1	3	1	0	0	0	0	0	0	0	0	0	0	5
V5	1	0	0	0	0	1	1	1	0	0	0	0	0	4
V6	0	0	0	0	1	0	0	0	0	0	0	0	0	1
V7	0	0	0	0	1	0	0	0	0	0	0	0	0	1
V8	0	0	0	0	1	0	0	0	0	0	0	0	0	1
V9	0	1	0	0	0	0	0	0	0	0	0	0	0	1
V10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
V11	0	0	0	0	0	0	0	0	0	0	0	1	1	2
V12	0	0	0	0	0	0	0	0	0	0	1	0	1	2
V13	0	0	0	0	0	0	0	0	0	0	1	1	0	2
Degree	3	8	2	5	4	1	1	1	1	0	2	2	2	

Pattern p1

Pattern p2

isolated vertex c

Figure-5 Adjacency matrix a[13,13]

Figure-4 is a graph when isolated vertex order is changed. Figure-5 is an adjacency matrix for the graph in figure-4. From this observation figure-5 results in five components which is wrong.

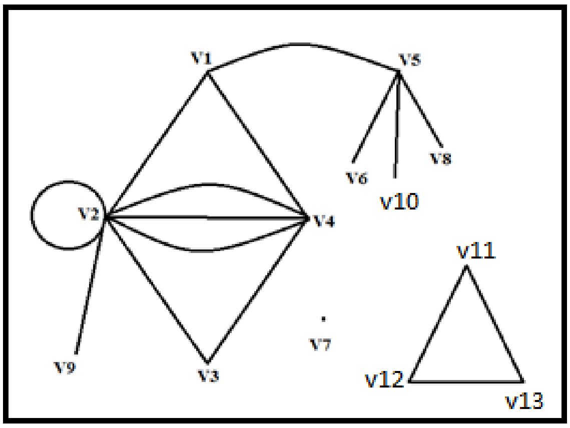

Figure-6 Graph with component vertices order changed.

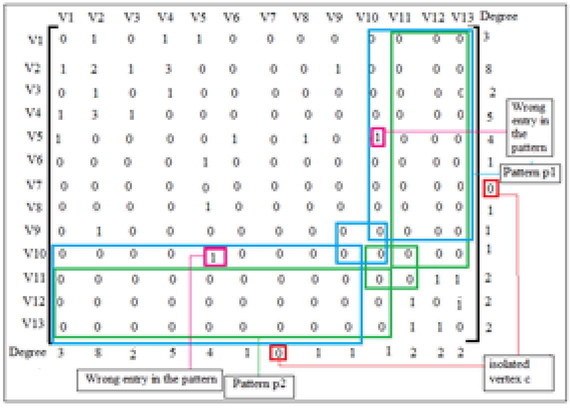

Figure-7 Adjacency matrix a[13,13]

Fgure-6 shows graph when the order of vertices is changed within the component. In figure-6 the isolated vertex is named as V7 which is suppose to be included for first copmonent. Hence the adjacency matrix gives wrong observation as shown in figure-7.

3.1.1.Algorithm:

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

Output:c- number of isolated vertices, p- number of pattern, k-number of components in a graph .

Method: c=0,p=0, k=0, flag=0

1. for i=0 to n
2. sum[i]=0
3. for j=0 to n
4. sum[i]+=a[i][j] //degree of each vertices
5. end for j
6. end for i
7. for i=0 to n
8. if(sum[i]==0)
9. c++
10. end step 8 if
11. end i for loop
12. for i=0 to n
13. for j=0 to n
14. if(i==j) // diagonal elements
15. if(((a[i][j]==0) && (a[i][j+1]==0) &&(a[i+1][j]==0) && (a[i+1][j+1]==0)) || ((a[i][j]==2) && (a[i][j+1]==0) && (a[i+1][j]==0) && (a[i+1][j+1]==2)))
16. for l=i to 0
17. for m=j to n
18. if(a[l][m]==0)
19. Continue
20. else
21. flag=1
22. exit
23. end step 18 if
24. end m for loop
25. end l for loop
26. if flag=0
27. p++
28. end step 26 if
29. end step 15 if
30. end i for loop
31. end j for loop
32. k=c+p+1

3.1.2.Time complexity:

The time complexity for this algorithm is $9n^2+15n+8$. Time complexity always depends on the number of vertices in a graph. The complexity for this algorithm is $\Theta(n^2)$.

$$T \alpha (n^2+8)$$

Table 1: Time complexity

	n=0	n=1	n=2	n=3	n=4	n=5
T	8	32	74	134	212	308

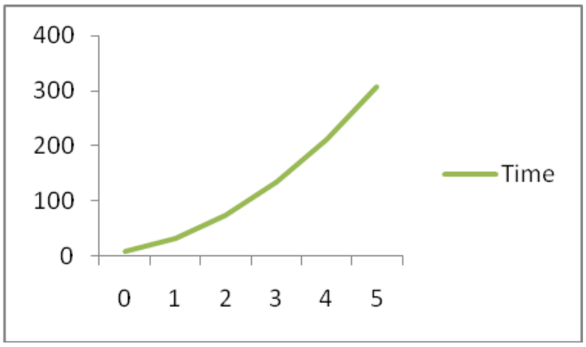

Fig-8: Graph of time versus number of vertices

3.2.Algorithm to find connection not allowed graph from adjacency matrix:

For any given graph if there are no direct or undirect edges between any vertices Vi and Vj then they are called as not connected vertices. If graph G represents network and vertices V represents nodes in a network then if there are no direct or undirectconnection between vertices indicates that the connection or communication between Vi and Vj is not possible without altering the network architecture. Connection not possible matrix can be determined from adjacency matrix and a new matrix is formed with the following conditions, if diagonal elements are 0 then it ismarkedas 2 to indicate self-loops. If diagonal elements are 2 then it is marked 0. All elements of adjacency matrix with 0 except diagonal elements are updated to 1 else if the elements are non-zero then it is updated as 0. Once the matrix is obtained graph is drawn for the same which given connection not allowed graph.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
V1	2	0	1	0	0	1	1	1	1	1	1	1	1
V2	0	0	0	0	1	1	1	1	0	1	1	1	1
V3	1	0	2	0	1	1	1	1	1	1	1	1	1
V4	0	0	0	2	1	1	1	1	1	1	1	1	1
V5	0	1	1	1	2	0	0	0	1	1	1	1	1
V6	1	1	1	1	0	2	1	1	1	1	1	1	1
V7	1	1	1	1	0	1	2	1	1	1	1	1	1
V8	1	1	1	1	0	1	1	2	1	1	1	1	1
V9	1	0	1	1	1	1	1	1	2	1	1	1	1
V10	1	1	1	1	1	1	1	1	1	2	0	0	1
V11	1	1	1	1	1	1	1	1	1	0	2	0	1
V12	1	1	1	1	1	1	1	1	1	0	0	2	1
V13	1	1	1	1	1	1	1	1	1	1	1	1	2

Figure-9: Adjacency matrix for not allowed connection graph

Figure-9 is an adjacency matrix for not allowed connection of graph in Figure-1. Figure-10 is a graph for the adjacency matrix in Figure-9. The presence of edge between any two vertices in Figure-10 shows that the connection between that two vertices is not possible.

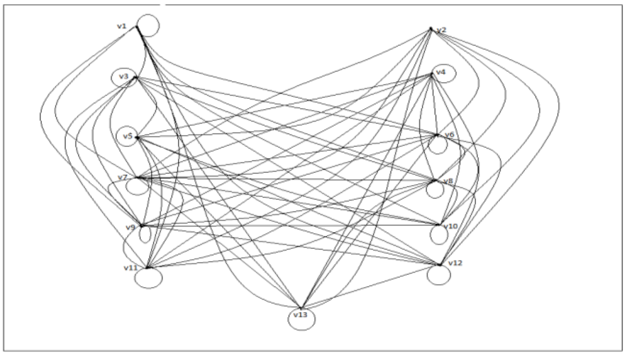

Fig-10: Graph for not allowed connection.

3.2.1.Algorithm:

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

Output:ac[n][n]-Adjacency matrix of connection not allowed graph .

Method:

1: for i=0 to n

2: for j=0 to n

3: if i==j //diagonal element

4: if a[i][j]==0

5 : ac[i][j]=2

6: else if a[i][j]==2

7: ac[i][j]=0

8: end step 7 if

9: end step 5 if

10: end step 3 if

11: if a[i][j]==0

12:ac[i][j]=1

13: end step 12 if

14:else if a[i][j]>0

15: ac[i][j]=0

16: end step 15 if

17: end step 1 for loop

18: end step 2 for loop

3.2.2.Time complexity:

The time complexity for this algorithm is $9n^2+9n+3$. Time complexity always depends on the number of vertices in a graph. The complexity for this algorithm is $\Theta(n^2)$.

$T \propto (9n^2+9n+3)$

	n=0	n=1	n=2	n=3	n=4	n=5
T	3	21	57	111	183	273

Tabel 2: Time complexity.

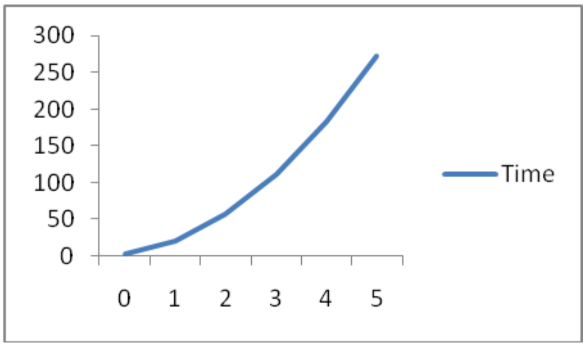

Fig-11: Graph of time versus number of vertices

IV. CONCLUSION:

This methodolgy can be used to find number of components in a graph and to find not allowed connections of the graph. This can be used in networks, electronic circuits, maps and so on. More useful to find need of routers to establish new connections in existing networks. The sum of anyrows or columns of adjacency matrix indicates the load on that particular node, which can be extended to load balancing.

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AUTHORS PROFILE

Prajwala.N.B Mysuru, Karnataka. MTech in Computer Science in the year 2016 from University of Mysuru.Bachelor of Engineering in Computer Science in the year 2013. Was selected as an intern to L&T, Mysuru during 2015. Worked as an intern in Aplusintellitech solution for one year on embedded c and on image processing.Worked as a team lead in aplusintellitech solution.Worked as software developer in Inqola.Also worked as quality analyst. Was faculty cum research associate in the department of computer science, Amrita School of arts and science, Mysuru, Amrita VishwaVidyapeetham, mysore, Imdia. Have published three research articles on image processing which are indexed in scopus, "Defect Detection in Pharma Pills Using Image Processing" in International Journal of Engineering & Technology during 2018, "Identification of Fake Notes and Denomination Recognition" and "Facial Expression Recognition by Calculating Euclidian Distance for Eigen Faces Using PCA" in IEEE explorer. Successfully presented research paper "Matching of Iris pattern using image processing" in the conference "Internantional conference on science and innovative engineering and technology" and two research papers in the conference " The recent innovation in computing, communication & intelligent system" which was held during April 2019. Got best paper award for the paper entitled "An efficient stack based graph traversal method for network configuration".

Indumathi S.M., Mysuru, Karnataka, MSc in mathematics in yuraj's college Mysuru during 2017,Bsc in computer Application in the year 2003 from University of Mysuru, Worked as computer faculty at school during 2004 and 2005.Worked as Assistant HR, also worked as Inventory Executive.Currently working as faculty associate in Amrita school of arts and science, Mysuru,.Interested to do research onGraphtheory, chromatic numbering andcryptography. Currently working on cryptography using Euler phi function. Project done on "Maruthicar distribution management system" using C programming in Bsc. Attended Seminar "Aiming at Inner Motivation for Tapping Human Resources for Varied Competencies" while pursuing Msc. Did Seminar on Cardioid tracing in Msc.Have attended 103rd Indian Science Congress held at University of Mysore from January 3 to 7,2016. Successfully presented paper in the conference " The Recent Innovation in Computing, Communication &Intelligent System" which was held during April 2019 in Amrita VishwaVidyapeetham, in Mysuru.