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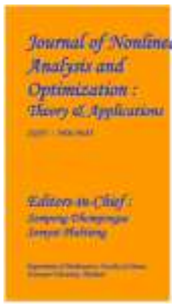

A STUDY ON SEMIGRAPH

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Abstract
Graph theory is widely used to prove many mathematical theorems, models, various applications and techniques to solve problems in different fields of science and technology in addition to mathematics. These fields include computer science, chemistry, biology, digital image processing, website designing, software engineering and operations research. A graph is denoted as $G(V,E)$. A graph consists of set of vertices V and set of edges E. The vertex is the point at which two edges meet, an edge is a line by which two vertices are connected with each other. A Semigraph S is a pair (U,E), where U is a nonempty set whose elements are called vertices of S and E is a set of ordered $n-$ tuples $n \geq 2$ of distinct vertices called edges of S that satisfies certain conditions. The present work is focus on the introduction, terminology, interpretation of Semigraph and its applications in the various fields of science and technology

Keywords
Semigraph, Factorization, Incidence matrix, Regular semigraph, Uniform semigraph, Splicing system, Dendroid, Bipartite, Minimal edge, Cartesian products, Domination, Fuzzy semigraph, Cospectral and Laplacian of semigraph

Introduction
Graph theory is nothing but a branch of Discrete Mathematics. Graph Theory is the study of graphs which are mathematical structures not only used in computer science but in many fields. Two problem areas are mainly considered. Problems such as classical problems and problems from an application. The classic problem is defined with the help of graph theory as connectivity, cut, path, flow, colouring problems and theoretical aspects of graph drawing. The problems from an application focus on experimental research and implementation of graph theory algorithms. Graphs are important because graph is a way of expressing information in pictorial form. A graph shows information that equivalent to many words. Many problems that are considered difficult to determine or implement can easily be solved by graph theory. There are many types of graphs as part of graph theory. Each type of graph is related to a particular property. One of these graphs is used in many applications for troubleshooting. Because of the representation power of graphs and flexibility many problem can be represented and solved easily
The father of graph theory was the great Swiss Mathematician Leonhard Euler. In 1973 he introduced graph theory to solve the problem of Konigsberg bridge. Graph theory is the study of relationships using vertices connected by edges. It is a helpful tool to quantify and simplify systems. Hypergraphs are introduced in 1973 by Berge. Hypergraphs are similar to basic graphs in that their edges are sets of any number of vertices rather than edges that only connect two vertices. This implies that every graph is merely a subset of hypergraphs. Semigraphs are introduced by E. Sampath Kumer in the year 2000. In this article, the semigraph and its properties were discussed. Also some operations of

semigraphs, Isomorphic Properties of Fuzzy semigraphs, Factorization, Bipartite theory and applications of semigraphs were discussed. Mainly domination numbers of semigraphs was discussed.

Abbreviations

G – Graph
S –Semigraph
H − Hypergraph
U – Vertex Set
E – Edge Set
A – Adjacency matrix
Fa – Signed adjacent dominating function
γ – Domination Number
γ_{sa} - Signed adjacent domination number
E_m - Matrix energy

Review of Semigraph

[1] A semigraph is an extension of a graph in which each edge is a N-tuple that satisfies certain constraints and can have two or more vertices. Semigraphs are defined, illustrated by a number of examples. We have a variety of definitions of each concepts like adjacency, degrees etc. In fact, the beauty of semigraphs lies in the variety of definitions/concepts, all of which coincide for graphs.

A semigraph S is a pair (U, E) where U is a nonempty set whose elements are called vertices of S and E is a set of ordered $n-$ tuples $n \geq 2$ of distinct vertices called edges of S and satisfying the following two conditions:

- any two edges have atmost one vertex in common
- any two edges $E_1 = (u_1, u_2 \dots u_r)$ and $E_2 = (v_1, v_2, \dots v_s)$ are said to be equivalent if and only if

    (a) $r = s$ and
    (b) either $u_k = v_k$ or $u_k = v_{n-k+1}$ for $1 \leq k \leq n$.

The vertices in a semigraph are divided into three types namely end vertices, middle vertices and middle – end vertices, depending upon their positions in an edge. The end vertices are represented by thick dots, middle vertices are represented by small circles, a small tangent is drawn at the small circles to represent middle – end vertices. Vertices of semigraphs represented by points and edges by lines in graphs. Since the edges in hypergraph are sets it become difficult to define concepts like Eularian, Hamiltonian etc. But one can easily introduce these concepts in semigraphs because the elements of an edge are arranged in an order. In this article the author has been discussed semigraphic matrices, optimal routing, sub edges, partial edges, walks, trails, paths, cycles and its length. Also removal of a vertex and an edge was discussed.

[2] Representation of a semigraph by matrices, namely, adjacency matrix, the incidence matrix, and the consecutive adjacency matrix also the 3 – matrix of a semigraph are defined. The incidence matrix, together with the consecutive adjacency matrix, determines a semigraph uniquely. Also, the 3 – matrix of a semigraph determines uniquely. A spanning dendroid of a connected semigraph S is a spanning connected sub semigraph of S without strong cycles and whose edges are partial edges of S. Matrix Dendroid theorem was proved. Also determination of genus, a topological invariant for different types of semigraphs on a compact orientable 2 – manifold surface, embedded, planer and exterior face have been studied. The genus of a semigraph S is defined as the minimum number of handles or holes which must be added to compact orientable 2 – manifold surface such that S can be embedded on the resulting surface.

In case of strong circuit matrix,

- The number of nonzero entries in each row is equal to the number of partial edges of cardinality 2 in the corresponding circuit.
- A column of all zero corresponds to a non circuit edge.

- The permutation of any two columns in a strong circuit matrix corresponds to relabeling of partial edges.
- The permutation of any two rows in a strong circuit matrix corresponds to relabeling of strong circuits

In case of strong path matrix,

- A column of all zeros corresponds to an edge that does not lie on any path between x and y.
- A column of all nonzero entries corresponds to an edge that lies in every path between x and y.
- There is no row with all zeros.

[3,4] Semigraph opens a scope for plenty of new significant results, which may or may not in graph theory. The problem of factorization in semigraph and obtained a necessary and sufficient condition for $1e$ – factorability of a particular type of regular semigraph, degree, edge degree, end vertex degree, subedge, sub semigraph, saturated spanning sub semigraph, regular semigraph, edge chromatic number, edge bipartite and factorization of semigraphs were studied. Two edges of a semigraph are said to be edge disjoint if they have no common vertex and they are said to be e – disjoint if they have no common end vertex. The most vital condition for a graph to have a 1 – factor is that the number of vertices is even. But this is not necessary for a semigraph. Tutte's theorem for graph theory which gives the necessary and sufficient condition for a graph to have a 1 – factor is also not true in semigraph theory. All the complete semigraphs of even vertices are not $1e$ $-$ factorable, a semigraph S is n – factorable if its end vertex graph G_e is n – factorable, Every n – regular complete semigraph of even number of vertices is 1 – factorable for every + ve integer n, Every edge bipartite d_e – regular connected semigraph is $1e$ – factorable and every d_e – regular semigraph of even number $(2n)$ of vertices having two edges of cardinality n each and all other edges having cardinality two each is $1e$ $-$ factorable

[5] Characterization of DNA structure after splicing in terms of semigraph to show some splicing graph properties. Semigraph folding for the DNA splicing system and show that any n – cut spliced semigraph $(n \neq 1)$ can be folded onto an edge and two semiedges at the maximum of four semigraph folding. Splicing is a model of the re combinant behavior of double stranded molecules of DNA under the action of restriction enzymes and ligases. A single standard of DNA is an oriented sequence of nucleotides. Some of the double standard DNA splicing languages need lesser number of iteration than the single standard DNA splicing system.

[6] Semigraph has been construct S_a, S_{ca}, S_e and S_{1e} - in the same pattern, also, construct bipartite graphs $CA(S), A(S), VE(S), CA+(S), A+(S)$, the equality of domination parameters in the bipartite graphs constructed with the domination and total domination parameter of the graphs S_a and S_{ca} . The domination and independence parameters for the bipartite semigraph, Xa - chromatic number, Xa $-$ hyper independent number and Xa- irredundant number have been discussed. Using these parameters, they have defined a Xa $-$ dominating sequence chain. Road networks can be easily modeled by using semigraphs. Traffic routing and density of traffic in junction has been studied through domination in semigraphs, definition of various domination parameters for an arbitrary graph and semigraph was discussed. In the bipartite theory of graphs, various parameters like X $-$domination sets, Y $-$dominating sets introduced, Bipartite domination was studied in detail. In a semigraph G with no isolates, every Ya $-$dominating set is a Xa $-$ dominating set.

[7] A djacency matrix associated with semigraph, necessary and sufficient conditions for a matrix to be semigraph have been defined. Spectrum of a semigraph and some of its spectral properties was studied. Semigraph prove to be a better model than graphs in all those applications where instead of two points to be connected by an edge. Unique representation of any discrete structure in matrix form is important for applications in computer secience. Cardinality of an edge E in a semigraph S is the number of vertices lying on that edge. Two vertices in a semigraph are said to be adjacent if they belong to the same edge and are said to be consecutively adjacent if in addition they are consecutive

in order as well. A semigraph with $n = 2$ is a graph. Hence it can be seen as a natural generalization of graphs. A semigraph is linear hypergraph H with an order given to each edge of H. The adjacency matrix associated with a semigraph as defined, it shed more light on the properties of linear hypergraph. The adjacency matrix satisfies the following two conditions (i) A is real and symmetric, λ is real (ii) The multiplicity of λ as a root of the characteristic equation det(λ I – A) = 0 is equal to the dimension of the space of eigenvectors corresponding to λ. The adjacency matrix of one graph can be obtained by row and column permutations of the adjacency matrix of the other matrix. When two adjacency matrices are similar, they have same spectrum. Two semigraphs are said to be cospectral if they have same spectrum. If two semigraph is isomorphic then they have cospectral but the converse is not true.

[8] The well known concept of matchining of graph theory has been discussed in the setting of semigraphs resulting in few new concepts like maximal vertex, saturated matching, minimal edge – saturated matching and optimum matching which have no parallels in graphs. A cut vertex in a semigraph is the vertex whose removal increases the number of components of S and a bridge is an edge whose removal increases the number of components of S. If there is a bridge in a semigraph then, there exist two cut vertices incident with the bridge. A non separable semigraph is the one which is connected, non trival and has no cut vertices. An edge bipartite semigraph is a semigraph which has no any odd s – cycles. A dendroid is a connected semigraph without s – cycle. A dendroid is an edge bipartite semigraph and in fact, it is a generalization of a tree. The maximum size of a matching in S equals the minimum size of its vertex cover. In case of an ordinary graph a maximum matching saturates largest number of its vertices, but the same is not always true for semigraph. In other words, a matching in a semigraph may saturate largest number of vertices though it may not be maximum one. Therefore, it is not out of context to formalize this situation in the form of a definition which may help characterization of distinguishing aspects of semigraphs, also introduce the concept of total adjacent domination and deduce some relations between adjacent domination and the total adjacent domination in particular type of matching in semigraphs. The concepts of subedge and partial edge of a semigraph g motivate us for defining two different types of path, a path p is said to be an s-path (strong path) if any two consecutive vertices on it are also consecutive vertices of an edge of S otherwise, it is said to be a w-path (weak path). Thus an s-path in a semigraph consists of edges and partial edges only. An s −path is an s −cycle (strong cycle) if its beginning and end vertices are same. A semigraph S is connected if there is a w-path or an s-path between any two vertices of S.

[10, 11,12, 13] The basic characteristic of all types of vertices have been discussed in detail. In particular, four types of degrees have been defined for each vertex and relationship among them have been studied in detail. Also four types of associated graphs and size of each of them corresponding to the given semigraph have been discussed. There are four types of adjacency is defined between any two vertices in a semigraph S, namely adjacent , consecutively adjacent, e – adjacent, $1e$ – adjacent. Similarly the degrees are defined as degree of a vertex, edge degree of a vertex, adjacent degree of a vertex, consecutive adjacent degree of a vertex. The adjacency of two vertices does not imply the consecutive adjacent, but the converse is always true. The number of e – adjacent vertices to an end vertex v in a semigraph is equal to the number of edges for which v acts as an end vertex. The number of e – adjacent vertices to a middle vertex is always zero. Every graph can be considered as a semigraph with no middle and middle end vertices. In this case the end vertex graph is the same graph. The semigraph containing end vertices and middle end vertices but not middle vertices then the end vertex graph G associated with S has pendent vertices, components but not isolated vertices. The concept of adjacency between vertices in a semigraph plays a vital role in the domination theory. End domination of cartesian product of a class path semigraphs. In this article, path semigraphs and its cartesian products were defined. A path semigraph means, a path semigraph in which every edge contains exactly one middle vertex. Here the results has been defined the simple path semigraph with n edges. In 2021, the authors has been discussed a – dominations in semigraphs, If S has no a – isolates, D is the minimum a – dominating set implies $V - D$ is an a – dominating set, also the dominating number of cycle and path semigraphs. The a – domination number of different type of semigraphs and its associated graphs have also been discussed. The authors discussed ca – domination numbers by using Cartesian product. A subset D of U is said to be $ca -$ dominating set if for every v belongs to $U - D$ there exists an vertex u belongs to D such that u and v are consecutively adjacent. The minimum cardinality of such a set D is called $ca -$ domination number of the semigraph S .

[9] A semigraph S is vertex labeled, if its n – vertices are labeled by distinct symbols. Various results on enumeration of vertex – labeled semigraphs containing non – adjacent edges and number of vertex labeled semigraphs with two adjacent s – edges are obtained. Also the number of vertex – labled semigraphs on 1 to 8 vertices is calculated and non – isomorphic semigraphs by introducing one or more middle vertices in various classes of graphs such as a path, unicyclic graphs with adjacent pendant edges, unicyclic graphs with two non adjacent pendant edges have been studied.

[14] The polynomial energy of a semigraph using the concept of energy of a polynomial was studied. Also the matrix energy Em of a semigraph using the singular values of its adjacency matrix, some partial semigraphs of a given semigraph, such that matrix energy of partial semigraph is necessarily less than or equal to the matrix energy of a given semigraph have been studied.

[15] The properties of signed adjacent dominating function for a class of semigraph and present their signed adjacent domination number was discussed. Domination in semigraphs has many practical applications such as providing a city with minimum number of security officers, possible light arrangements in the offices, etc. Defined the terms such as open adjacent neighbour set, open consecutive adjacent neighbor set, closed adjacent neighbour set, closed consecutive adjacent neighbour set, adjacency domination number and consecutive adjacency domination in semigraphs such as adjacency domination number, consecutive adjacency domination number were discussed. Let $S = (U, E)$ be a semigraph, with $U = \{u_1, u_2, \cdots, u_n\}$ as a vertex set and $E = \{e_1, e_2, \cdots, e_m\}$ as an edge set. Let v_i, v_j belongs to $e = (v_1, v_2, \cdots, v_k)$ for some $e \in E$. Let $d_e(u_i, u_j)$ denote the distance between u_i and u_j in the graph skeleton of e .The distance $d_e(u_i, u_j)$ is well-defined as each pair of vertices in semigraph belongs to at most one edge. Let C and B be, respectively, the strong circuit matrix and the partial edge incidence matrix of semigraph S, whose columns are arranged using the same order of partial edges. If semigraph S having cardinality ≥ 3 and does not contain middle-cum-end vertex then the product BCT or $CB\ T = 0$, null matrix

[16]Many binary operations have been defined in graph theory to derive its properties using set theoretical terminology. Semigraph provide a wide scope for defining various types of fundamental operations and explore its hidden properties. Semigraphs mainly contains two types of edges called subedges and partial edges which play a very prominent role in the application of resolving traffic problems, representing family relationships. We employ some of these fundamental operations in semigraphs with respect to partial edge, subedges and equal edges. The properties of partial edges, sub edges and equal edges give rise to various types union, intersection, decomposition and ring sum concepts in semigraphs. The main objective of the author is to define full edge operation, end – vertex operation and subedge operation and applications of these operations in Eulerian semigraphs. The existence of isomorphism between a semigraph and its adjancy graph, consecutive adjancy graph, end – vertex graph is established. Relaxing the conditions imposed in all the definitions better generalizations are possible. The application of elementary operations to the p – Eulerian semigraph is also discussed. The authors has been defined signed adjacent dominating function, signed adjacency domination number, signed consecutive adjacent dominating function and signed consecutive adjacent domination number of semigraph. Likewise signed adjacent domination number for star number for star semigraph, strongly complete semigraphs was discussed.

[17] Isomorphism, weak isomorphism and co-weak isomorphism of fuzzy semigraphs were introduced and some of their properties have been studied. End vertex isomorphism ($ev -$ isomorphism) , edge isomorphism ($e -$isomorphism) and adjacency isomorphism (a-isomorphism) of fuzzy semigraphs were defined. Properties of effective edges and effective fuzzy semigraphs under isomorphism have been studied. Also, it is proved that isomorphism is an equivalence relation and weak isomorphism is a partial order relation. Also concept of fuzzy semigraphs, effective fuzzy semigraph and some properties were discussed. The degree sequence and the degree set of fuzzy graphs and their properties have been discussed. Semigraph have wide range of applications in Railway network, Road network, Telecommunication systems, etc. The results, isomorphisms between fuzzy semigraphs is an equivalence relation was studied. Weak isomorphism need not preserve the e – effective and the semi – effective of the edges, isomorphism is transitive, weak isomorphism between fuzzy semigraphs is a partial order relation, the semi – effectiveness of G need not imply the semi – effectiveness of G^1 when G is co – weak isomorphic to G^1 was proved.

[18] Cartesian product can be used to find paths or routes in networks. It is used to explore all possible connections or routes between the nodes of two semigraphs. Most computer displays images as a raster of points called pixels that can be addressed by their coordinates. These coordinates are ordered pairs and hence elements of cartesian product. Domination in semigraph has applications to several fields. Domination arises in facility location problem, where the number of establishments, such as hospitals, shops, etc. Concept from domination also appear in college/school bus routing, electrical circuits and land surveying, google maps etc. It is also used in Wireless Sensor Network(WSN), for instance, in safety and military applications for the purpose of monitoring and tracking geographic boundaries. The water system minimum cost flow problem is solved using the successive shortest path by semigraph. Here end vertices represent dams, middle vertices represents ponds and the edges represent canals. Remaining vertices are middle vertices, it represent a small water sources like ponds, lake etc. We define all possible roots between the vertices , here all roots are connected each other. For producing hytro - electricity we select a water source by using domination for avoiding lack of water. By defining the adjacency matrix of a semigraph in a unique way such that this matrix is symmetric opens up a pandora's box from which one can choose any problem starting with spectra of various semigraphs to defining/generalizing results similar to graphs. We have just initiated this study which is expected to result in rich theory regarding semigraphs and also generate many applications, especially in the field of upcoming IOT and AI. Cartesian product of two semigraph with two middle vertex was discussed, and its minimul a – domination number is calculated. The formation of more complex structure from the well known simplest structure is a general way of thought in all end eavours, and the extension of the live properties of easiest structure to the toughest structures is an usual attempt.

[19] Various types of regular semigraphs using the concept of the degree of a vertex in a semigraph have been studied. The concept of the degree of a vertex has variations due to the variety of vertices in semigraphs. Two more regular semigraphs have been defined with the help of the binomial incidence matrix of a semigraph which determines the semigraph uniquely up to isomorphism. The interconnection between the variety of regular semigraphs has been discussed. The minimum number of edges in the semigraph which is regular of all kinds have been given. Vertices in semigraph have four variety of degree. So, each kind of degree can be used to define a different type of a regular semigraph. There are four variety of regular semigraph defined on the basis of degree concepts. A semigraph is R – regular if the binomial incidence matrix of the semigraph has constant row sum, it is C – regular if the binomial incidence matrix of the semigraph has constant column sum and in RC – regular semigraph the sum of each column is equal and it is the same as the sum of each row. A uniform semigraph is R – regular if and only if it is vertex – regular. Also if a semigraph is D and CAD – regular then it is ED – regular and if a semigraph is ED and CAD regular then it need not be D – regular. In a semigraph S, a vertex v and an edge E are said to cover each other if v belongs to

E . A set S of vertices that covers all edges of a semigraph S is said to be a vertex cover for S. The vertex covering number of S is the minimum cardinality of a vertex cover for S. An edge cover for a semigraph S is a subset of $X = X(S)$ that covers all vertices of the semigraph $S = (U, E)$ and the minimum cardinality of such a subset is called the edge covering number of S. A set X of vertices of a semigraph S is said to be independent if no edge is a subset of X. The maximum cardinality of such a set is the vertex independence number of S. Similarly, a set L of edges of a semigraph S is said to be independent if no two of the edges in L are adjacent.

[20, 21, 22] Semigraph Laplacian is same as the graph Laplacian. Spectral properties of Laplacian of semigraphs was defined, also different types of star semigraphs and their Laplacian eigenvalues was discussed. The author provide evidence that shows that spectral theory for semigraphs generalizes the spectral theory of graphs. The Laplacian matrix is symmetric positive semi – definite which is a very well understood class of matrices, and hence it opens doors to several research problems in spectral semigraph theory.

For a semigraph, we define following types of vertices and edges:

(1) u_i is said to be a pure end vertex if it is an end vertex of every edge to which it belongs.

(2) u_i is said to be a pure middle vertex if it is a middle vertex of every edge to which it belongs.

(3) u_i is said to be a middle end vertex if it is middle vertex of at least one edge and end vertex of at least one other edge.

(4) An edge $e = (u_1, u_2, \cdots, u_k)$, $k \geq 2$ is said to be full edge if u_1 and u_k are pure end vertices.

(5) An edge $e = (u_1, u_2, \cdots, u_k)$, $k > 2$ is said to be an half edge if either $u_1$or u_k (or both) are middle end vertices.

(6) An edge $e = (u_1, u_2)$ is said to be a quarter edge if both u_1 and u_2 are middle end vertices while $e = (u_1, u_2)$ will be half edge if exactly one of $u_1$and u_2 is a middle end vertex and other is a pure end vertex. For a full edge $e = (u_1, u_2, \cdots, u_k)$, (u_i, u_{i+1}) , for all $1 \leq i \leq k - 1$ is called a partial edge of e while for a half edge $e = (u_1, u_2, \cdots, u_{k-1}, u_k)$, (u_1, u_2) is called partial half edge of e if u_1 is middle end vertex, (u_{k-1}, u_k) is a partial half edge of e if u_k is middle end vertex and (u_i, u_{i+1}) , for all $2 \leq i \leq k-2$ are partial edges of e . Thus,any half edge can have at most two partial half edges. Also an half edge is a partial half edge iff it contains only two vertices and half edge with partial half edges must have at least 3 vertices. Consider a semigraph $S = (U, E)$, in this article, the author discussed the eigen values of the Laplacian matrix of S , the Laplacian of S is positive semi-definite, and S is connected if and only if $\lambda_2 > 0$. Along the similar lines of graph theory bounds on the largest eigenvalue, upper and lower bounds on the largest Laplacian eigenvalue of S and enumerate the Laplacian eigenvalues of some special semigraphs such as star semigraph, rooted 3-uniform semigraph tree. Here, the Laplacian of semigraph is positive semi-definite. This makes the study of spectra of semigraphs interesting. The Laplacian eigenvalues of the rooted 3-uniform semigraph tree was studied.

Conclusion

In this article, different definition of various semigraphs is described, also providing the basic idea of semigraphs. All the required terminologies of semigraph are covered by these definitions. Different applications of semigraph have been identified and divided as per their fields. It will explain where different semigraphs used in real world applications and getting the deep knowledge of semigraph also its relevance with different subjects like operating systems, Networks, Databases, software engineering, Biology, Chemistry, Operation Research and Digital Image Processing etc. Many important OR problems are solved using semigraphs. A semigraph is used to model the transportation of commodity from one place to another.

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