On Transmission of COVID-19 in Terms of Semigraph

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Abstract: - Semigraph Theory plays a significant role in most of the areas of science and technology. Every situation can be understandably articulated in terms of suitable graphs by using various approaches of Semigraph theory. Considering the recent advent of the pandemic in the world and the precautions taken for prevention of the COVID-19, it is the most appropriate way to utilize the Semigraph models with practical as well as theoretical aspects to prevent this epidemic. This work defines the two types of variable sets depending on the time factor. In this project, the mechanism of infection of the virus has been described in a simple way. The prevention method of the virus infection includes the partition of the semigraph i.e. isolating from other non-infected persons. The whole world is using the same method while controlling the infection of viruses.

Key-Words: - COVID-19, Semigraph, Bipartite semigraph, Dendroid, Transmission, Social distancing.

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1 Introduction

COVID-19 is a transferrable disease caused by the coronavirus that recently started in Wuhan, China. This highly transferrable virus and subsequently the disease were completely shadowy to the world before its outbreak. Considering the recent COVID-19 virus and its transmission across the world, it is important to understand and study the virus's spread and impact. The disease caused by this virus has become a pandemic and many countries have been devastated badly. COVID-19 has devastated almost all the countries in various dimensions. Using the **semigraph theory** approach, this work helps users to understand and visualize this disease, its impact, and its spread. The different semigraph method presented in this project shows the virus, and its growth type is presented using semigraph theory.

Almost 50 million cases of COVID-19 (coronavirus) and more than 6 million deaths have now been reported worldwide. The largest part of the epidemic in the world comes into sight to be stationary or declining. A good number of countries have undergone worse conditions in the early stages of their epidemics and few of them were affected early in the pandemic and are now starting to see an improvement in their cases. Hence, it is the most important and inevitable to prevent the spread of such types of epidemics. As we know, mathematical modeling awards different astonishing inspirations and tools to study different communal as well as technical problems and interpret solutions. This will show the way to find practical solutions to a variety of problems and help to continue the harmony of mankind.

The studies, [1], [2], [3], [4], [5], [6], and especially, the authors in, [4], in the year 1994 generalized the definition of graph to semigraph. Some definitions of semigraphs are given below:

Semigraph: A semigraph G is an ordered pair (V, X) where $V = \{v_1, v_2, \dots, v_n\}$ is a nonempty set whose elements are called vertices of G, and $X = \{e_1, e_2, \dots, e_m\}$ is a set of r-tuples, called edges of G. The edges consist of distinct vertices, for various $r \geq 2$, satisfying the following conditions:

i. Any two edges have at most one vertex in common.

ii. Two edges $(x_1, x_2, x_3, \dots, x_p)$ and $(y_1, y_2, y_3, \dots, y_q)$ are considered to be equal if and only if
(a) $p = q$ and
(b) either $x_i = y_i$ for $1 \leq i \leq p$, or $x_i = y_{p-i+1}$ for $1 \leq i \leq p$.

Thus the edge $e_i = (x_1, x_2, x_3, \dots, x_t)$ is the same as the edge $(x_t, x_{t-1}, \dots, x_1)$, where x_1 and x_t are said to be the end vertices, whereas $x_2, x_3, \dots, x_{t-1}$ are called the middle vertices of the edge e_i.

Subedges and Partial Edges: A subedge of an edge E = (v_1, v_2 ,…………v_m) is a k-tuple É = (v_{i_1}, v_{i_2}………v_{i_k}) where $1 \le i_1 <$………$< i_k \le n$.

A partial edge of E is a (j−i+1)-tuple E(v_i, v_j) = (v_i, v_{i+1},…., v_j), where $1 \le i \le n$. Thus a subedge E′ of an edge E is a partial edge if, and only if, any two consecutive vertices in E′ are also consecutive vertices of E.

Removal of Vertex from an edge:

Bipartite Semigraph: Let G= (V, X) be a semigraph. G is bipartite if its vertex set V can be partitioned into sets {V_1,V_2} such that V_1&V_2 are independent.

***e*-Bipartite Semigraph**: G is e-bipartite if V can be partitioned into sets {V_1,V_2} such that both V_1 and V2 are e-independent.

Strongly Bipartite Semigraph: G is Strongly bipartite if V can be partitioned into sets {V_1,V_2} such that V_1&V_2 are Strongly independent.

Dendroid: A dendroid is a connected Semigraph without Strong cycles and a forest is a semigraph in which every component is dendroid. Further, every dendroid is e-bipartite and hence bipartite. Clearly, every dendroid is also edge bipartite.

Variable set: Let *S* be the set of vertices of a Semigraph *G*. If the strength of *S* changes with time *t* then it is said Variable set, denoted by S_t.

Strictly Increasing Set: Let S_{t_1}(V) be the set of vertices at time t_1, if $|S_{t_1}(V)| < |S_{t_2}(V)|$, then the set is defined as Strictly increasingly Set. But, if $|S_{t_1}(V)| > |S_{t_2}(V)|$, then the set can be defined as Strictly Decreasing Set. Pictorially, as shown in Figure 1.

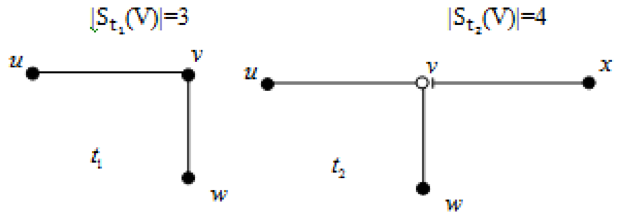


Fig. 1: The strictly increasing set with respect to time (t_1, t_2).

In, [1], [2], [3], [4], [5], [6], and especially, the authors in, [2], they construct the model of transmission of Covid-19 which describes below:

2 Analysis of COVID-19 infection defining some new term

Let us try to coin some new terms such that our study becomes easy and simple. Since the infection rate of the virus is rapid, many factors can be stated as preventive methods such as SOCIAL DISTANCING, VACCINATION, WEARING MASKS, and so on.

Suppose x_i denotes the **infected person** at time t_i where $i = 0,1,2,\dots,n,n+1$ and $R(x_i)$ denotes the **rate of spread** of the virus infection at time t_i by the carrier x_i. It is worth mentioning that in this paper, we will be concerned with the middle vertices only as the approach is being done through semigraph.

Here x_0 and x_{n+1} are the person who was initially infected by the virus but now are free of the virus or died, i.e. $R(x_0) = R(x_{n+1}) = 0$. Hence all the responsibility of spreading the virus is borne by x_i, $i = 1,2,\dots,n.$ We define some terms below:

(i) D_{sd} be the term denoting **Social distancing**, i.e. $|D_{sd}| > 2m$, where *m* = meter.

(ii) E_v denotes the people who are fully vaccinated.

(iii) E_v' denotes the people who are not fully vaccinated yet.

Mathematically, Let $Y_i \subset E_V$ then the rate of being infected or spreading the virus gradually roll down, i.e. for $i = 1,2,\dots,k$, $R(E_v) < 100\%$, since the efficiency of vaccines is not 100%.

Let $Z_i \subset E_v'$ then the rate of being infected by the virus is high and chances of spreading the virus are also higher, i,e.

$$R(Z_i) > 50\%(\uparrow), \quad \text{for } i = 1,2,\dots,k.$$

i.e. They have more than a 50% chance of spreading the virus infection.

We describe the feasible infection of the COVID-19 virus diagrammatically below.

Let $S_i = \{x_i \mid i = 1,2,...\}$. Gradually with the increase of time, the cardinality of S_i increase i.e. $|S_{i+1}| > |S_i|$ at different time t_i, $i = 1,2,...$ Specifically, the explosion of COVID-19 is presented in Figure 2 and Figure 3.

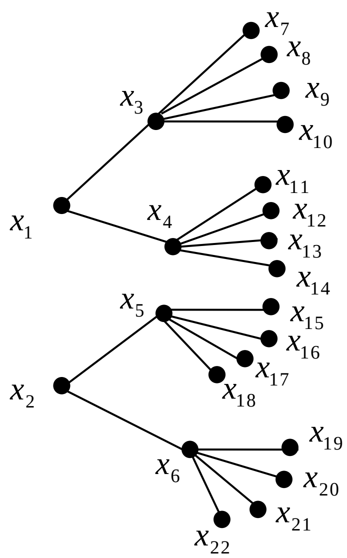


Fig. 2: The explosion of COVID-19 in the type of Chain Reaction

Now we use our semigraphical approach to the spread of the virus:

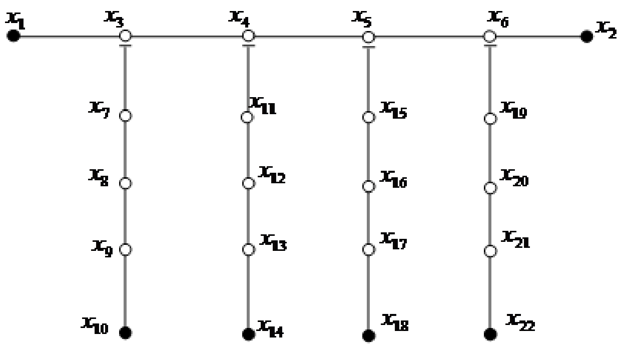


Fig. 3: The explosion of COVID-19

3 Models Describing the Transmission of COVID-19

In, [1], [2], [3], [4], [5], [6], and especially, the authors in, [2], construct a semigraphical model of transmission of COVID-19 virus.

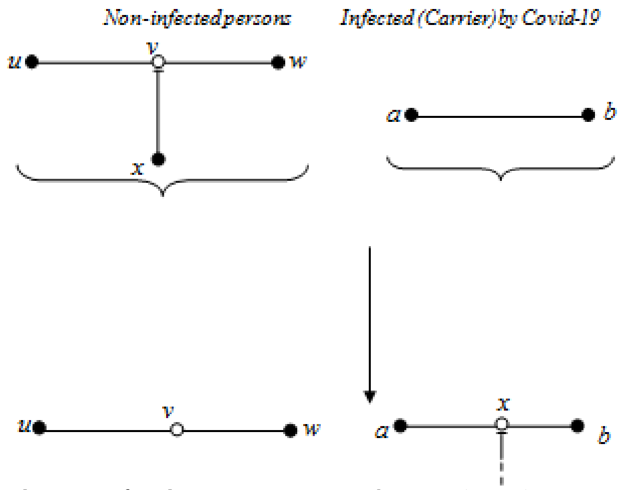
Semigraphical Model -I :

In this model, we discuss the transmission of the COVID-19 virus simply.

Let *N* = the set of non-infected persons and *X* the set of infected persons. (Carrier of virus).

Let $y \in N$ be any element. If *y* tries to make a bond i.e. come close contact with the element of *X*, then *N* becomes $N - \{y\}$ and *X* becomes $X \cup \{y\}$.

Semigraphically, we illustrate with the help of an example (Figure 4). Let $N = \{u, v, w, x\}$ it is written as in the set of edges $E_N = \{(u, v, w), (v, x)\}$ and $X = \{a, b\}$ then it is written in the set of edge $E_X = \{(a, b)\}$. Here we describe the mechanism of infection in Semigraphical Model-I



Reduce Non-infected persons *Here the vertex (person) x comes with the contact with vertices a and b, got infected. Now x gains huge momentum to infect i.e. building edges with new vertex (Non-infected)*

Fig. 4: The Semigraphical Model -I

Suppose the new carrier *x* has been exposed at the initial stage, then its rate of spreading infection will be zero i.e. $R(x) = 0\%$.

Now if we isolate the person at a separate place so that the person does not come in contact with anyone. That means the vertex cannot form any edge with the help of other new vertex/vertices, which is expressed in Figure 5 below:

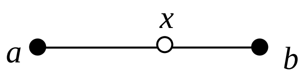


Fig. 5: Isolation procedure of the person infected by the virus x.

This acts as a single edge (a, x, b) where the capacity of building the edges by the vertices *x* has been broken down after it has been isolated.

Hence, for any number of elements from the set *N* coming in close contact with any element of *X* being exposed at the very initial stage, they create only a single edge with the capacity (rate of spreading) of $R(x)$ zero.

4 Semigraphical Model-II

In this section two Models using **Semigraph** of transmission of Covid-19. Apart from this, the growth rate of infected persons is analyzed.

4.1 Semigraphical Model-II

This model is one of the important models that clearly show the transmission of the virus in several stages. It is worth mentioning here that the person (vertex) who has come in close contact with the carrier has not been exposed initially. As described above (Figure 5) if the person/vertex *x* is not isolated at an early stage and makes it free then from it the virus gets transmitted at an unknowing rate. This fact is illustrated below (Figure 6):

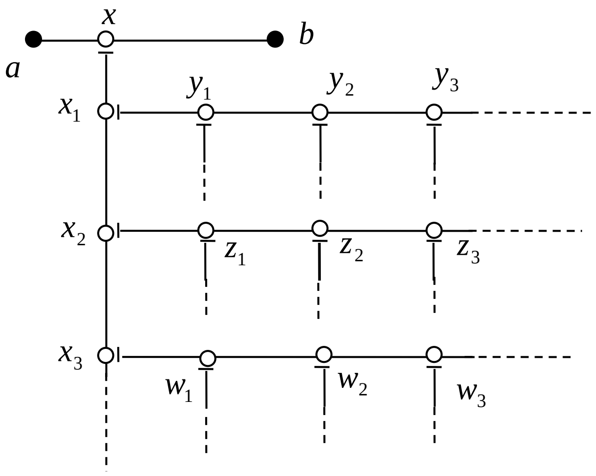


Fig. 6: Transmission growing at an unknown rate.

In this stage, the infection rate increases rapidly. Each infected person with the virus may have more chance to spread the indefinitely.

4.2 Growth Rate

The Growth Rate of virus can be divided into two types:

(i) Simple Growth Rate/ Linear Growth Rate
(ii) Multiple Growth Rate

(i) Simple growth rate: Let us explain this growth with a suitable example. In this growth, the number of infected people by the virus (carrier) remains constant.

Let $X = \{a,b\}$ be the carrier of the virus infection. i.e. $|X| = 2$ and a person *x* comes close contact with any element of *X* then the set *X* will be $X_1 = X \cup \{x\}$ and $|X_1| = 3$. Suppose the infected person (vertex) comes into contact with three other non-infected persons (vertices) x_1, x_2 and x_3. Then the set X_1 becomes enlarge to $X_2 = X_1 \cup \{x_1, x_2, x_3\}$ where $|X_2| = 6$. A figure (Figure 7) given below shows this phenomenon nicely.

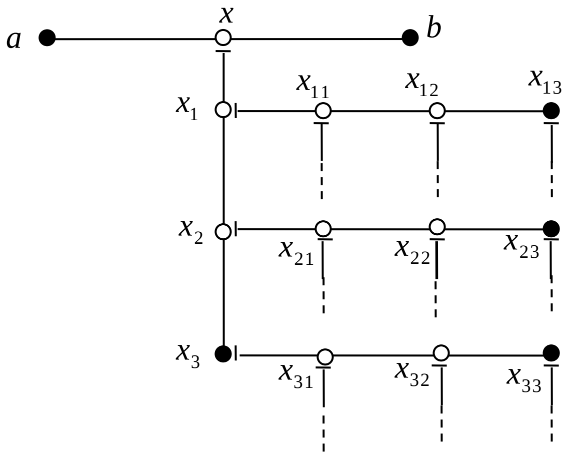


Fig. 7: The growth of the virus linearly in Semigraph (Model-I).

From the figure,

$e = (x, x_1, x_2, x_3)$ is the chain of infected persons (vertices) infected by *x*.

$e_1 = (x_1, x_{11}, x_{12}, x_{13})$ created by x_1.

$e_2 = (x_2, x_{21}, x_{22}, x_{23})$ created by x_2.

$e_1 = (x_3, x_{31}, x_{32}, x_{33})$ created by x_3.

$e_{11} = (x_{11}, ...)$ created by x_{11}.

$e_{12} = (x_{12}, ...)$ created by x_{12}.

And so on.

The number of distinct new COVID-19 cases (edges) is mentioned in Table 1 corresponding to the number of infected persons (vertices).

Table 1. The number of distinct new COVID-19 cases

NUMBER OF INFECTED PERSONS (VERTICES)	DISTINCT NUMBER OF COVID-19 CASES (EDGES)
1	$3.1 = 3 = 3^1$
3	$3.3 = 9 = 3^2$
9	$3.9 = 27 = 3^3$
27	$3.27 = 81 = 3^4$
$k = 3^n$	$3.k = 3.3^n = 3^{n+1}$

Hence we can conclude that each edge of a chain of infection created by any carrier yields **r** no. of COVID-19 Cases (new except itself).

Then **K** edges yields $\mathbf{r^{k+1}}$ no COVID-19 Cases.
Where $\mathbf{K=r^k}$ no of edges.
Diagrammatically, Figure 8 presents the simple growth in Semigraph (Model-II).

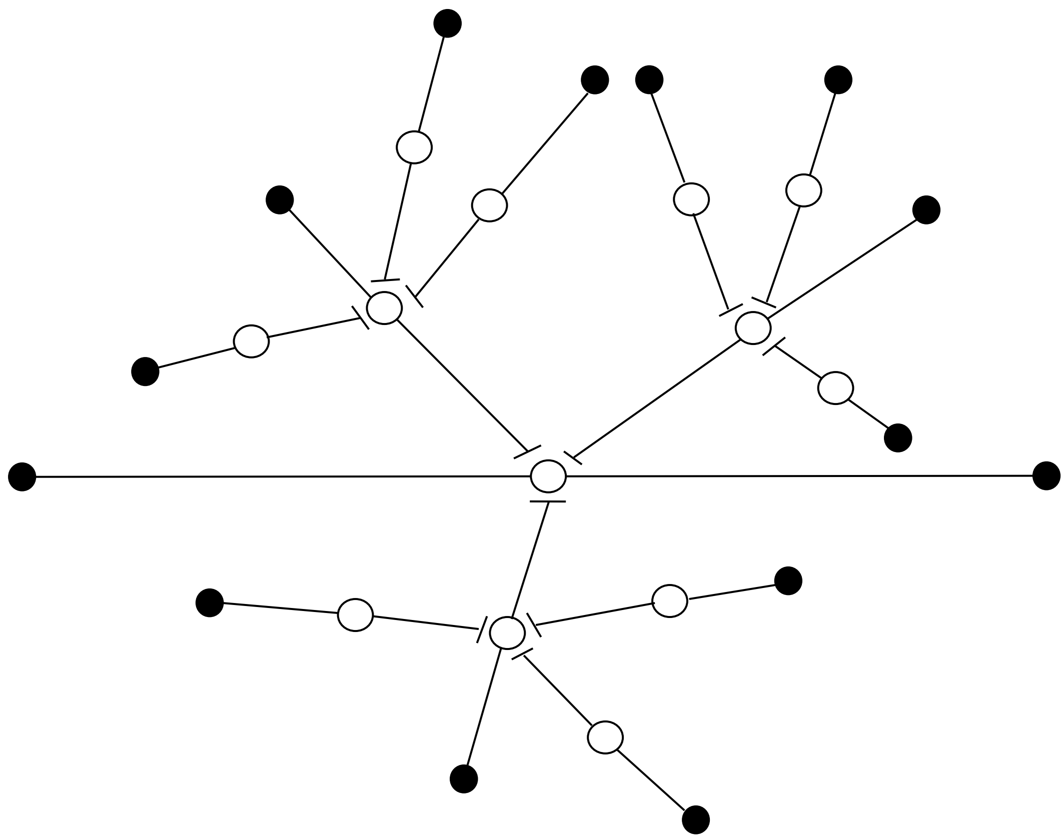


Fig. 8: The simple growth in Semigraph (Model-II)

5 Conclusion

This paper concludes that there is an infinite scope of mathematics for the research as well as resolving social problems like COVID-19 and technical problems.

Semigraph Theory plays a significant role in most of the areas of science and technology. Every situation can be understandably articulated in terms of suitable graphs by using various approaches of Semigraph theory. Considering the recent advent of the pandemic in the world and the precautions taken for prevention of the COVID-19, it is the most appropriate way to utilize the Semigraph models with practical as well as theoretical aspects to prevent this epidemic.

6 Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest or other ethical conflicts concerning this research article.

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