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Virus Graph and COVID-19 Pandemic: A Graph Theory Approach

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Abstract. Graph theory plays significant role in every field of science as well as technology. Every situation can be articulated in terms of suitable graphs by using various approaches of graph theory. Considering the recent pandemic in the world and the precautions taken for prevention of the COVID-19, it is the most appropriate way to exercise the graph models with theoretical as well as practical aspects to control this epidemic. This paper defines the variable set, variable graphs and their types with respect to variable vertex sets and variable edge sets. Depending upon the nature of the pandemic, there are four types of Virus graphs. Virus graph I and III are not so perilous for all living beings. Although, Virus graphs II and IV are extremely hazardous for the harmony of the world. In view of different aspects for expand of pandemic, growth types of virus graphs are divided in 1-1, 1-P and 1-all growth types. The COVID-19 initially was in Virus graph-I type, but presently it is in Virus graph-II types. We present the table involving the number of infected people after n days with respect to different values of P and growth rates with I0 = 100. Moreover, the country wise starting dates of stages of the virus graph-I and II are specified. The concept of cut sets is applicable for prevention of COVID-19 and the whole world is using the same analogy.

Keywords: virus graphs; COVID-19; pandemic; epidemic.

1.1 Introduction

COVID-19 is the transferrable disease caused by the recent coronavirus recently started in Wuhan, China. This virus and subsequently the disease were shadowy to the world before its outbreak. Considering the recent COVID-19 virus and its spread across globe, it is important to understand and visualize the virus spread and impact. The disease caused by this virus has become pandemic and many countries are affected badly. Using graph theory approach, this paper helps users to understand and visualize this disease, impact and spread. The different graph method presented in this paper shows virus, its growth type is presented using graph theory. The number of persons who are affected and prevention is also presented in this paper. The conclusion of this paper is that there is infinite scope of mathematics for the research as well resolving social problems like COVID-19 and technical problems.

The reader will refer [2], [5], [7], [21] for the absolute dealing with the subject matter. All Graphs considered in this paper are simple as well as connected. The neighbor of the vertex v in graph H is the set of all the vertices adjacent to the vertex v in H. A graph with n vertices and without any edges is called the Null graph and it is denoted by Nn [2]. A simple connected graph, in which degree of each vertex is 2, is called a cycle graph. Cn is the cycle graph on n vertices [21]. A graph, in which one vertex is adjacent to n pendent vertices, is called the star graph. It is symbolized by $K_{1,n}$. Here, $|V(K_{1,n})| = n+1$ along with $|E(K_{1,n})| = n$ [10].

The paper is organized as follows. Basic terms of graph are presented in Section 1.1. Motivation and related work is presented in section 1.2 and 1.3 respectively. Graphical theoretical model that emphasizes on Virus Graph I, II, III and IV is presented in section 1.4. Section 1.5 and 1.6 discusses on growth rate and its types. Country wise stages of Virus graph I and II is presented in section 1.7. Growth rate of COVID-19 is predicted and presented in section 1.8. This paper is summarized with future outlook in section 1.9.

1.1.1 Partite Graphs

A graph H is n- partite graph if V(H) = V_1 U V_2 U …., U V_n, where all V_i are disjoint and every edge of H joins a vertex of V_i and V_j for $i \neq j$. If n = 2, 3, 4 then graphs are called Bipartite, Tripartite and four partite respectively [2].

1.1.2 Cut Sets

A set of edges of a connected graph H, whose removal disconnects H, is called the disconnecting set of H. The smallest disconnecting set is called the cut set of H [5],[21].

1.1.3 Corona Product of Graphs

The corona product of H and K is denoted by H ▫ K and obtained from a copy of H and |V (H) | copies of K, joining each vertex of H to all vertices of the graph K. This graph product was initiated by mathematicians Frucht and Harary in 1970 [1], [17].

1.2 Motivation

Almost 2.5 million cases of COVID-19 (corona virus) and more than 160,000 deaths have now been reported worldwide [21]. The largest part of the epidemic in the world comes into sight to be steady or declining [7]. A good number countries are immobile in the early stages of their epidemics and few of them were affected early in the pandemic are now starting to see an improvement in cases. Hence, it is the most important and essential to prevent the spread of such types of epidemic [10]. As we know, mathematical modelling award different astonishing inspiration and tools to study different communal as well as technical problems and interpret solutions. This will lead to find the practical solutions of a variety of problems and helps to continue the harmony of the mankind.

1.3 Related Work

Giulia Giordano et al [5] proposed an innovative epidemic model which distinguishes between infected people depending on whether they have been confirmed by considering their symptoms. Non diagnosed peoples can spread virus rapidly than diagnosed people. Therefore the divergence between diagnosed and non-diagnosed plays an important role for the deterrence of a pandemic. A fuzzy theory and deep learning networks help to enhance for acquiring superior stochastic insights concerning the epidemic growth is experimented [7]. A deep learning based Composite Monte-Carlo (CMC) showed better results than simple Monte Carlo (MC) which will be obliged for decision makers for greater ranges of the future promises of epidemic and pandemic [3]. In paper [18], it is studied that due less and incorrect information about COVI-19, there is no any exact model which can predict spread of the pandemic. Every model has different levels of predictive efficiency.

By analyzing data in few countries, it is noted that an infection reached to peak around 10 days after the controlling measures are initiated. The growth rate of infected people was slowly decreasing during this period. But, especially the growth rate in Italy remains exponential. Hence, quarantine is insufficient and need strict measures [19]. In paper [20], the authors have made a mathematical model for the epidemic by applying linear differential equations. By identifying patterns and analyzing desired data, it is concluded that the growth rate is dynamic or exponential depending upon precautions taken by people. Shinde Gitanjali et al [9], presented and meticulously discussed different predictive analytic models as well as algorithms for the number infected cases in the near future. Moreover, the Prophet predictive analytics algorithm is implemented on the Kaggle dataset and its predictions are studied in their research work. The following new terms are defined for constructing the pedestal of mathematical modelling of any types of pandemic or COVID-19.

Critical decision making is difficult due to uncertainty caused by novel coronavirus epidemic. Fong et al [10] presented deep learning and fuzzy based prediction method for the future possibilities of coronavirus and its impact. The present events and its future behavior is presented using Composite Monte Carlo simulation method. The difficult task is accurate forecasting of destiny of an epidemic is presented by Fong et al [11] using augmentation of existing data, panel design for selection of best forecasting model and its fine tuning of parameters of each model. Deep learning method was presented by Hu et al [12] for forecasting of COVID-19.

Based on the lung CT scan images, Rajinikanth [13] presented a system for detection of COVID-19. This proposed method is based on Otsu and a meta-heuristic Harmony search algorithm. Using graph theory, data classification was proposed by Kamal [14] which is based on De-Bruijn graph with MapReduce framework.

After evaluation of related work, there is a need for the mathematical modelling and visualization of COVID-19 using graph theory is essential to spread awareness among many stakeholders.

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1.3.1 Variable Set

A set S is said to be Variable set if elements of the set S changes with respect to time or some rule. That is, the set S is not constant set. Its cardinality changes with respect to time. Sv is the notation of variable set. In the variable sets, time units depend upon its nature. According to the scenery of the cardinality of the set S, there are three types of sets.

- Increasing Variable Set: A variable set Sv is said to be increasing variable set if $| S_v (x) | < | S_v (y) |$, whenever $x < y$, where x and y are different times.
- Decreasing Variable Set: A variable set S_v is said to be decreasing variable set if $|S_v (x) | > |S_v (y) |$, whenever $x < y$.
- Non Decreasing Variable Set: A variable set S_v is said to be non-decreasing variable set if $|S_v (x) | \leq |S_v (y) |$, whenever $x \leq y$.
- Non Increasing Variable Set: A variable set S_v is said to be non-increasing variable set if $|S_v (x) | \geq |S_v (y) |$, whenever $x \leq y$.
- Stable Variable Set: A variable set S_v is said to be stable variable set if $|S_v (t) |$ = constant, for any time t. However, the set is a variable set. Elements of the set S vary according to time, but the $|S_v (t) |$ is steady, for any time t.

1.3.2 Variable Graph

A graph H is said to be a vertex variable graph if V (H) or E (H) is variable sets. Variable graphs are also known as V- graphs. Big network graphs are variable graph. There are two types of variable graphs.

1.3.3 Edge V-Graph

A variable graph H is said to be edge V- graph if E (H) is a variable set and V (H) is the stable variable set.

1.3.4 Vertex V-Graph

A variable graph H is said to be vertex V- graph if V (H) is a variable set and E (H) is the constant variable set.

1.3.5 n-partite V- Graphs

A variable graph H is said to be n-partite V- Graph if

i. $V (H) = V_1 \cup V_2 \cup V_3,. . . ,V_n$ where $V_1 , V_2 ,V_3 , . . ., V_n$ disjoint variable sets having different characteristics.
ii. There exists a bond on the link or edge between vertices of Vi & Vj , for i , j and $i \neq j$.

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1.3.6 Bipartite V- Graph

A variable graph H is said to be Bipartite V- Graph if

i. V (H) = V_1 U V_2,, where V1 and V2 are disjoint variable sets with different characteristics.
ii. There exists a bond on the link or edge between vertices of V_1 and vertices of V_2
iii. There is no any bond among the vertices of V_1 only or V_2 only.

These types of graphs are denoted by BV_2. In BV_2, a vertex x of V_1 is said to be **Active Vertex** or element if there exists a bond between x and at least one vertex of V_2 or x is trying to build a bond or edges to the vertices of V_2. Moreover, x is ready for the sharing some characteristics. Other vertices of V_1 are known as the Passive Vertices. A vertex y of V_2 is said to be Active Vertex or element if there exists a bond between y and at least one vertex of V_1 or y is aiming to build a bond or edges to the vertices of V_1. Other vertices of V_2 are known as the **Passive Vertices**.

1.4 Graph Theoretical Model

1.4.1 Virus Graph I

A Bipartite V-graph H is said to be Virus Graph I (VRG-I) if

i. V (H) = I U N, where, I be the variable set of vertices have some special properties or infected by virus and N be the variable set of vertices not having a virus.
ii. If x ∈ I, creates a bond or an edge with the vertex y ∈ N or vice versa, then y is shifted to I and N = N - {y}.
iii. If x ∈ I, is recovered by treatment or lost properties of virus then, x is shifted to N and N = N U {x}. The diagrammatic representation of VRG-I is shown in fig.4.1.

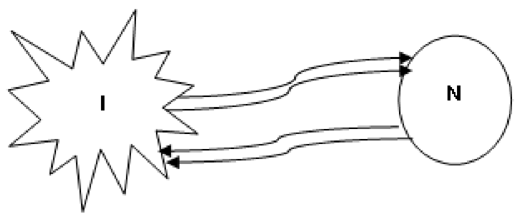

Fig.4.1 Virus Graph I

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1.4.2 Virus Graph II

A Tripartite V-graph H is said to be Virus Graph II (VRG-II) if

i. V(H) = I U N U F, where, I be the variable set of vertices having the virus, N be the variable set of vertices not having virus and F be the set of vertices which can never be shifted to I or N.
ii. If x ∈ I, creates a bond or an edge with the vertex y ∈ N or vice versa, then y is shifted to I and N = N - {y}.
iii. If x ∈ I, is recovered by treatment or vanished properties of virus then, x is shifted to N and N = N U {x}.
iv. Vertices of I are shifted to F if the vertices are infected forever. Therefore, S is the non-decreasing variable set. This is represented in Fig.4.2

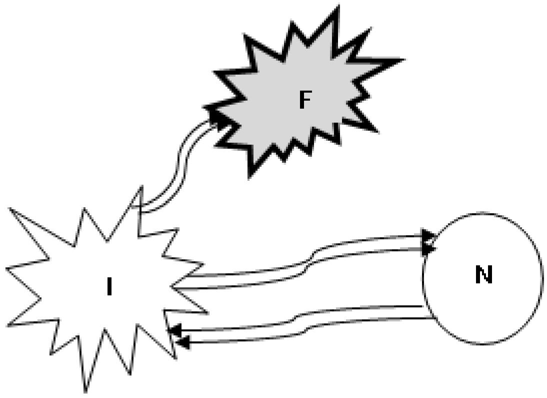

Fig.4.2 Virus Graph II

1.4.3 Virus Graph III

A Tripartite V-graph H is said to be Virus Graph III (VRG-III) if

i. V(H) = I U N U S, where, S be the set of vertices which is never infected by the virus.
ii. If x ∈ I, creates a bond or an edge with the vertex y ∈ N or vice versa, then y is shifted to I and N = N - {y}.
iii. If x ∈ I, is recovered by treatment or lost properties of virus then, x is shifted to N and N = N U {x}.
iv. Vertices of N, with some additional features, can be shifted to variable set S. Furthermore, the vertices of S are protected by a shield of antivirus or some special vaccines. The vertices of V can't be directly transformed into S, but transformed to N and N to S. Con-

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sequently, S is the non-decreasing variable set. This occurrence is shown in fig 4.3.

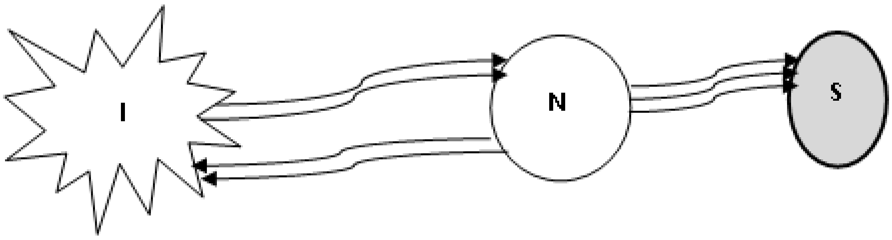

Fig.4.3 Virus Graph III

1.4.4 Virus Graph IV

A four partite V-graph H is said to be Virus Graph IV (VRG-IV) if

i. V(H) = I U N U S U F, where, F be the set of vertices which can never be shifted to I or N or S.
ii. If x ∈ I, creates a bond or an edge with the vertex y ∈ N or vice versa, then y is shifted to I and N = N - {y}.
iii. If x ∈ I, is recovered by treatment or lost properties of virus then, x is shifted to N and N = N U {x}.
iv. Vertices of N, with some additional features, can be shifted to variable set S. Furthermore, the vertices of S are protected by a shield of antivirus or some special vaccines.

Vertices of F can be never shifted to any other set. The elements of F are having philosophy “infected once is infected forever”. It is shown in fig. 4.4

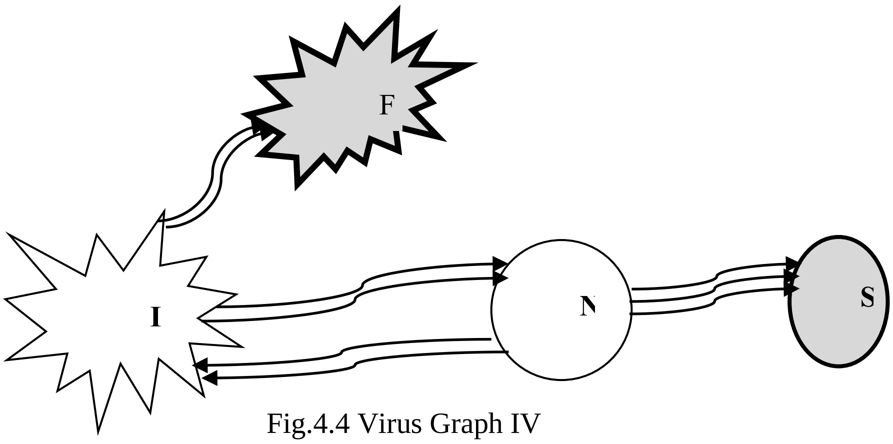

Fig.4.4 Virus Graph IV

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Virus Graph: A variable graph is said to be a Virus graph if it belongs to class of either Virus graph-I or Virus graph-II or Virus graph-III or Virus graph-IV.

1.5 Growth Rate

The growth rate of any V-graph is the rate of increase of active elements minus the rate of increase of passive elements.

1.6 Types of growth

There are three types of growth of any virus, according to graph theory.

1.6.1 One – One Growth:

A growth is said to be one – one or 1- 1 growth if one active element of the variable set infects only one active element of another set at that instant. This growth is articulated as the corona product of cycle graph with K_1. Here Cm is the cycle graph having r active elements, which are elements of the variable set I. Additionally, K_1 is an individual active element of the variable set N. It is shown in Fig. 4.5

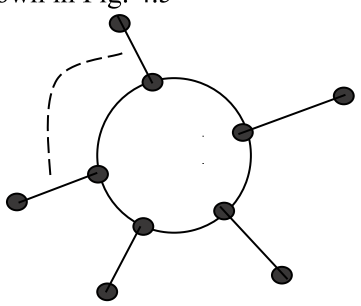

Fig. 4.5 One - One Growth

- **Growth rate is constant**

Without loss of generality, assume that there are 30 % active elements in each set. Also assume that the number of infected people is extremely less than the total population. In this growth type, every day 30 % new patients are increased in the set I. Let I_0 be the number of people infected by the virus at initial stage. Let In be the number of people will be infected after n days. As a result,

$$I_1 = I_0 + (0.30)\, I_0 = 1.3 * I_0, \qquad (1.1)$$

$$I_2 = I_1 + (0.30)\, I_1 = 1.30 * I_1 = 1.3\,(1.3 * I_0) = (1.3)^2\, I_0 \qquad (1.2)$$

In general, $I_n = (1.3)^n * I_0$.
Let R be the rate of the virus per unit tine and I_0 be an initial number of infected people. Therefore,

$$I_1 = I_0 + R\, I_0 = (1 + R)\, I_0, \qquad (1.3)$$

After second time interval,

$$I_2 = I_1 + R\, I_1 = (1 + R)\, I_1 = (1 + R)^2\, I_0. \qquad (1.4)$$

After n time intervals, the number of infected people will be

$$I_n = (1 + R)^n\, I_0 \qquad (1.5)$$

- **Growth rate is not constant**

Now, assume that the growth rate is different in each time interval as given table 1.1

Table 1.1. Growth rate and time interval

After Time ti	t1	t2	t3	t4	. . .	tn-1	tn
Growth Rate Ri	R1	R2	R3	R4	. . .	Rn-1	Rn

After the second time interval,

$$I_2 = I_1 + R_2\, I_1 = (1 + R_2)\, I_1 = (1 + R_2)(1 + R_1)\, I_0, \qquad (1.6)$$

$$I_3 = (1 + R_3)(1 + R_2)(1 + R_1)\, I_0, \qquad (1.7)$$

After n time intervals, the number of infected people is

$$I_n = (1 + R_n)\ \ldots\ (1 + R_2)(1 + R_1)\, I_0. \qquad (1.8)$$

Moreover, at time t_i, growth rate is R_i and R_i is repeated m_i times in the given interval. Hence,

$$I_n = (1 + R_1)^{m_1}\,(1 + R_2)^{m_2}\ \Lambda\ \ (1 + R_j)^{m_j} \qquad (1.9)$$

where $1 \le j \le n$ and $m_1 + m_2 + \ldots + m_j = n$.

Thus, the growth of the infected people is exponential. Consider the table 1.2 for the number of elements in I after nth days corresponding to various percentages of active elements with $I_0 = 100$.

Table 1.2. Number of elements in I after n[th] days with respect to active elements

No. of days	In (Growth 30 %)	In (Growth 1 %)	In (Growth 2 %)	In (Growth 3 %)	In (Growth 4 %)	In (Growth 5 %)	In (Growth 7 %)	In (Growth 10 %)	In (Growth 15 %)	In (Growth 20 %)
1	130	101	102	103	104	105	107	110	115	120
2	169	102	104	106	108	110	114	121	132	144
3	220	103	106	109	112	116	123	133	152	173
4	286	104	108	113	117	122	131	146	175	207
5	371	105	110	116	122	128	140	161	201	249
6	483	106	113	119	127	134	150	177	231	299
7	627	107	115	123	132	141	161	195	266	358
8	816	108	117	127	137	148	172	214	306	430
9	1060	109	120	130	142	155	184	236	352	516
10	1379	110	122	134	148	163	197	259	405	619
15	5119	116	135	156	180	208	276	418	814	1541
20	19005	122	149	181	219	265	387	673	1637	3834
25	70564	128	164	209	267	339	543	1083	3292	9540
30	262000	135	181	243	324	432	761	1745	6621	23738
35	972786	142	200	281	395	552	1068	2810	13318	59067
40	3611886	149	221	326	480	704	1497	4526	26786	146977
50	49792922	164	269	438	711	1147	2946	11739	108366	910044
60	686437717	182	328	589	1052	1868	5795	30448	438400	5634751
70	9463126845	201	400	792	1557	3043	11399	78975	1773572	34888896
80	130457239505	222	488	1064	2305	4956	22423	204840	7175088	216022846
90	1798463828896	245	594	1430	3412	8073	44110	531302	29027233	1337556525
100	24793351109	270	724	1	505	131	867	1378	1174313	828179745

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	660		922	0	50	72	061	45	2
120	47119673969 69860	330	3 1077 471	110 66	348 91	335 779	9270 907	1921944 500	317504237 378

In this growth type, by table 4.2, it seems that if growth rate is 30 %, then the number of infected people will reach to 1060 after 9th day, 19005 after the 20th day, 262000 after the 30th day and 24793351109660 after 100th day. But if growth rates are 1 %, 2%, 3%, 4% and 5%, then the number of infected people will be 245, 594, 1430, 3412 and 8073 respectively after 100th days. Therefore, the growth rate of any pandemic must be very less for the welfare of mankind.

1.6.2 One – P Growth

If one active element of the variable set (I) infects at most p active elements of another set (N) together at that instant, is called One – P growth or 1-P growth. In this case, Cm is the cycle graph having r active elements of variable set I and there is a group of P individual active elements of variable set N. Therefore, it is the corona product of the Cm with null graph having n vertices, which is shown in fig. 4.6.

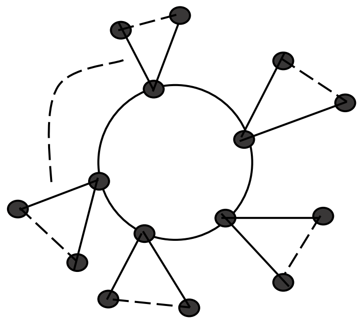

Fig. 4.6 One – P Growth

Without loss of generality, assume that there are R active elements in each set. R % new patients are increased every day in the set I. Let I0 be the number of people infected by the virus at initial stage. Let In be the number of people will be infected after n days.

As a result,

$$I_1 = I_0 + (R*P)\, I_0 = (1+ R*P) * I_0, \quad (1.10)$$

$$I_2 = I_1 + (R*P)\, I_1 = (1+ R*P)^2 * I_0 = (1.3)^2\, I_0 \quad (1.11)$$

In general,

$$I_n = (1+ R*P)^{n} * I_0. \quad (1.12)$$

The number of infected people will be doubled in at most in **Error! Bookmark not defined.** days.

If R = 0.01 and n = 2, then the greatest value of P is the value where I_0 will become doubled. Therefore, The greatest value of P is $(e^{0.34657} - 1) * 100 \approx 42$. Hence, growth is 1 – P type if the value of P $\leq$ 42. For the greater values of P, the growth type is 1- all growth.

1.6.3 One – All Growth

If one active element of the variable set infects all or more than 42 active elements of another set together at that instant, is called 1 – all growth. Such types of growth occur through water or air only. This is extremely perilous for living beings. Cm is the cycle graph having r active elements of variable set I and the group of the active elements of the variable set N. This is the corona product of Cm with all individual elements of null graph having more than 42 vertices. Its graph is given in fig. 4.7.

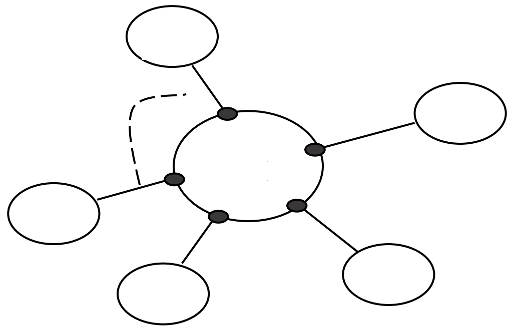

Fig. 4.7 One – All Growth

1.7 COVID-19

COVID-19 is a virus graph. At the initial stage, it was in the type virus graph-I. Let V (C) and E (C) are the variable vertex set (the set of people) and variable edge set of the COVID-19 graph C. Therefore, V(C) = I U N, where I be the variable set of people infected by the virus COVID-19 and N be the variable set of people not infected by the COVID-19. Some corona viruses can be transmitted from person to person, generally after close contact with an infected patient, for example, in a household workplace, or health care center.

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The continuity of the graph C can be disconnected by the disconnecting set. So, keep all vertices of either set in the disconnecting set.
That is

$$D = \{I\} \text{ or } D = \{N\} \tag{1.13}$$

Moreover, the cut set of C is {I} if $|I| \leq |N|$, otherwise, the cut set is {N}. At present, every country of the world is doing the same for controlling the effect of COVID-19. We isolate people of set I as well as N or quarantine the people of set I or N, as per the necessities.

Presently, COVID-19 is in the virus graph-II type. Moreover,

$$V(C) = I \cup N \cup F \tag{1.14}$$

where F be the set of people, who are infected permanently. The people of the set F will not be recovered by any medicine and will die in the near future. The whole world is suffering from the effect of this virus and everyone is fervently waiting for the vaccine of this virus.
The table 1.3 gives the country wise starting dates of stages of the virus graph-I and II.

Table 1.3. Country wise stages of the virus graph-I and II.

Sr. No.	Name of Country	Virus Graph- I from	Virus Graph- II from
1	Afghanistan	25-Feb-20	24-Mar-20
2	Africa	15-Feb-20	9-Mar-20
3	Australia	25-Jan-20	1-Mar-20
4	Bermuda	20-Mar-20	9-Apr-20
5	Bhutan	6-Mar-20	-
6	Bolivia	12-Mar-20	1-Apr-20
7	Brazil	26-Feb-20	18-Mar-20
8	Bulgaria	8-Mar-20	12-Mar-20
9	Cambodia	28-Jan-20	-
10	Canada	26-Jan-20	10-Mar-20
11	China	31-Dec-19	11-Jan-20
12	Colombia	7-Mar-20	22-Mar-20
13	Denmark	27-Feb-20	16-Mar-20
14	Egypt	15-Feb-20	9-Mar-20
15	Europe	25-Jan-20	15-Feb-20
16	Finland	30-Jan-20	22-Mar-20
17	France	25-Jan-20	15-Feb-20

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18	Germany	28-Jan-20	12-Mar-20
19	Ghana	13-Mar-20	22-Mar-20
20	Greece	27-Feb-20	12-Mar-20
21	Greenland	20-Mar-20	-
22	Hungary	5-Mar-20	16-Mar-20
23	India	30-Jan-20	13-Mar-20
24	Indonesia	2-Mar-20	12-Mar-20
25	Iran	20-Feb-20	23-Feb-20
26	Iraq	25-Feb-20	14-Mar-20
27	Ireland	1-Mar-20	12-Mar-20
28	Israel	22-Feb-20	21-Mar-20
29	Italy	31-Jan-20	27-Feb-20
30	Japan	15-Jan-20	13-Feb-20
31	Kenya	14-Mar-20	27-Mar-20
32	Kuwait	24-Feb-20	5-Apr-20
33	Malaysia	25-Jan-20	25-Mar-20
34	Nepal	25-Jan-20	-
35	Netherlands	28-Feb-20	7-Mar-20
36	New Zealand	28-Feb-20	29-Mar-20
37	North America	21-Jan-20	1-Mar-20
38	Oman	25-Feb-20	1-Apr-20
39	Pakistan	27-Feb-20	21-Mar-20
40	Peru	7-Mar-20	21-Mar-20
41	Poland	4-Mar-20	13-Mar-20
42	Russia	1-Feb-20	29-Mar-20
43	Rwanda	15-Mar-20	-
44	Singapore	24-Jan-20	29-Mar-20
45	South Africa	6-Mar-20	31-Mar-20
46	South America	26-Feb-20	8-Mar-20
47	South Korea	20-Jan-20	21-Feb-20
48	South Sudan	6-Apr-20	-
49	Spain	1-Feb-20	5-Mar-20
50	Sri Lanka	28-Jan-20	29-Mar-20
51	Sudan	14-Mar-20	15-Mar-20
52	Swaziland	15-Mar-20	18-Apr-20
53	Sweden	1-Feb-20	12-Mar-20
54	Switzerland	26-Feb-20	6-Mar-20
55	Taiwan	21-Jan-20	17-Feb-20
56	Thailand	13-Jan-20	1-Mar-20

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57	Turkey	12-Mar-20	19-Mar-20
58	Uganda	22-Mar-20	-
59	United Arab Emirates	27-Jan-20	1-Apr-20
60	United Kingdom	31-Jan-20	6-Mar-20
61	United States	21-Jan-20	1-Mar-20
62	Vietnam	24-Jan-20	-
63	Yemen	10-Apr-20	-
64	Zimbabwe	21-Mar-20	24-Mar-20

It is observed that if we take desired precautions, then we can control the spread of the epidemic or pandemic. There are few countries still in virus graph-I and most of the countries rapidly reached to virus graph-II.
After discovering the vaccine on COVID-19, it will be shifted to virus graph-IV type. Therefore,

$$V(C) = I \cup N \cup F \cup S, \qquad (1.15)$$

where S be the set of vertices which can never be infected by virus. That is all people in the set S are vaccinated by desired medicines.
In this situation, we need to increase the number of elements of the set S up to the whole population of the universal set. Hence, everyone will be free from the effect of the virus.
Moreover, hope that there should not be such types of pandemic, but if so, that must be Virus graph-III. This will help to preserve excellent harmony of living beings.

1.8 Growth rate of COVID-19

The growth type of the COVID-19 is 1- P growth. One person can infect at most $P \leq 42$ persons at a time. For the superior values of P, this growth is also called Small Community Spread.
The table 1.3 gives the number of infected people after n days with respect to different values of P and growth rates with $I_0 = 100$.

Table 1.3. Number of infected people with respect to R and P

Patient no.	I_n Growth Rate 1%		I_n Growth Rate 2%		I_n Growth Rate 3%		I_n Growth Rate 4%		I_n Growth Rate 5%	
	P =3	P =5	P=3	P =5	P =3	P =5	P =3	P =5	P =3	P =5

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1	103	105	106	110	109	115	112	120	115	125
2	106	110	112	121	119	132	125	144	132	156
3	109	116	119	133	130	152	140	173	152	195
4	113	122	126	146	141	175	157	207	175	244
5	116	128	134	161	154	201	176	249	201	305
6	119	134	142	177	168	231	197	299	231	381
7	123	141	150	195	183	266	221	358	266	477
8	127	148	159	214	199	306	248	430	306	596
9	130	155	169	236	217	352	277	516	352	745
10	134	163	179	259	237	405	311	619	405	931
11	138	171	190	285	258	465	348	743	465	1164
12	143	180	201	314	281	535	390	892	535	1455
13	147	189	213	345	307	615	436	1070	615	1819
14	151	198	226	380	334	708	489	1284	708	2274
15	156	208	240	418	364	814	547	1541	814	2842
16	160	218	254	459	397	936	613	1849	936	3553
17	165	229	269	505	433	1076	687	2219	1076	4441
18	170	241	285	556	472	1238	769	2662	1238	5551
19	175	253	303	612	514	1423	861	3195	1423	6939
20	181	265	321	673	560	1637	965	3834	1637	8674
21	186	279	340	740	611	1882	1080	4601	1882	10842
22	192	293	360	814	666	2164	1210	5521	2164	13553
23	197	307	382	895	726	2489	1355	6625	2489	16941
24	203	323	405	985	791	2863	1518	7950	2863	21176
25	209	339	429	1083	862	3292	1700	9540	3292	26470
26	216	356	455	1192	940	3786	1904	11448	3786	33087
27	222	373	482	1311	1025	4354	2132	13737	4354	41359
28	229	392	511	1442	1117	5007	2388	16484	5007	51699
29	236	412	542	1586	1217	5758	2675	19781	5758	64623
30	243	432	574	174	132	6621	2996	23738	6621	80779

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				5	7					
31	250	454	609	191 9	144 6	7614	3356	28485	7614	100974

If the growth rate is l % and P = 5, then the number of infected people will be doubled after 15 days, whereas, R= 5 and P = 5, then the number of infected people will be 244 after the 4th day, 1,164 after 11th day, 10,842 after the 20th day and 1,00,974 after 31st day. Thus the growth rate as well as the P value play a vital role in prevention of any types of epidemics.

1.8.1 Complexity

The Virus graph representation includes either adjacency matrix or adjacency list. The adjacency matrix is 2D matrix that has row and column combination. The combination may include growth rate and number of infected people. The complexity of representing this information will have $O(n^2)$. On the other side, if it is implemented using adjacency list, the complexity will be $O(v+e)$, where v is vertices and e is edges connecting those vertices.

1.8.2 Limitations

In this paper, the data under consideration is enormous and varying, consequently the size of virus graph is extremely large. The cut sets of the graphs recommended for the prevention of the COVID-19 is large but if handled logically, will award superior results. The growth rate is high, so practically difficult to measure, but mathematically it is simple to analyze.

1.9 Conclusions and Future Outlook

Mathematical modelling always plays very significant role in the smooth functioning of the world. The aim of this paper is to understand outbreak of COVID-19 using graph theory model. By applying different aspects of Mathematics, world's universal problems have had been consistently resolved. Concepts of graph theory have provided the mathematical modeling of the COVID-19. It has also been suggested methods to control the spread of some types of pandemic. Types of Virus graphs as well as growth rates are modeled by using graphs. Our analysis and study indicates that there is special need to identify minutiae of pandemic and apply astonishing theories for maintaining the smooth harmony of mankind. It seems that there is infinite scope of mathematics for the research as well as resolving social and technical problems of the world.

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