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A Neural Network based Model with Lockdown Condition for Checking the Danger Stage Level of COVID-19 Infection Risk

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Abstract: In December 2019, human history is observing a very strange time fighting an invisible enemy, the novel corona virus (COVID-19). Initially emerged in Wuhan, China and has swiftly spread to other parts of China and a number of foreign countries around the world. There is a current worldwide outbreak of a new type of corona virus (COVID-19). Governments are under increased pressure to stop the outbreak spiralling into a global health emergency. A series of mandatory actions have been taken by the municipal and provincial governments supported by the central government, such as measures to restrict travels across cities, contact tracing and case detection, guidance, quarantine and information to the public etc. At this stage, preparedness, transparency and sharing of information are crucial to risk assessments and beginning outbreak control activities. The main objective of this paper is to develop a neural network based algorithm involving lockdown condition between hidden layers for checking the level of COVID-19 infection risk from the pandemic data. The results show that India is in a good condition in comparison of other countries due to timely implementation of the lockdown.

Keywords: Artificial neural network, COVID-19, Corona virus, Lockdown.

I. INTRODUCTION:

Now a day, whole world is facing the major problem in the form of CORONA virus. WHO named it COVID-19.It had originated from a seafood wholesale market in Wuhan city, China in Dec 2019. COVID-19 spread human to human by close contact. If any infected person sneeze or cough any other healthy person is very close then there are high chances to infect a healthy person. Experts say that its symptoms come out after two weeks. The first case of COVID-19 in India was identified on 30 January 2020. In India, the number of COVID-19 infected cases and deaths reported per week have increased day by day (See Table-2).

Table 1: Number of newly reported COVID-19 cases in India

Week	Number of COVID-19 infected Cases		Number of Deaths Reported	
	New	Accumulated	New	Accumulated
26 January–1 February	1	1	0	0
2 February–8 February	2	3	0	0
9 February–15 February	0	3	0	0
16 February–22 February	0	3	0	0
23 February–29 February	0	3	0	0
1 March–7 March	31	34	0	0
8 March–14 March	63	97	2	2
15 March–21 March	186	283	2	4
22 March–28 March	635	918	16	20
29 March–4 April	2154	3072	55	75
5 April –11 April	4457	7529	167	242
12 April- 18 April	7262	14792	246	488
19 April-25 April	10150	24942	291	779
26 April-02 May	12834	37776	444	1223
03 May-09 May	21886	59662	758	1981

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As seen in Table 1, the number of newly confirmed cases and deaths per week has increased and a serious outbreak in India is a realistic outcome.

Unfortunately we are not able to make the medicine for the preventions of COVID-19. Experts deem that isolation and quarantine are the only ways to prevent COVID-19, by follow this way you can help self and protect others also. Following the advice of experts, all countries started lockdown. Will the lockdown actually help to prevent COVID-19? How long should it last? These are some of the questions public are grappling along with the COVID-19 virus.

While it is not possible to get precise answers to these questions, epidemiologists and policymakers turn to mathematical models to navigate the pandemic and help take critical decisions. These models, which extrapolate from existing data to predict the progression of an infectious disease outbreak, have come to play an integral role in infectious disease epidemiology. Ramanan Laxminarayan, director of the Centre for Disease Dynamics, Economics and Policy says that these models also aid experts understand if a health system is geared up in terms of medical personnel and equipment to tackle the infection.

Anderson & May (1979) and Thieme (2003) conclude that modelling and simulation are most important decision tools that can be helpful to control human and animal virus. Lloyd-Smith (2007) presents a simulation study exploring the bias, precision, and confidence interval coverage of maximum-likelihood estimates of k from highly over-dispersed distributions. Huppert & Katriel (2013) discuss to what extent disease transmission models provide reliable predictions. Mathematical modelling is a tool for making strategies to control such as HIV, childhood infections, influenza, and vector borne infections (Zaman et al. (2017)). Kumar (2017) has proposed and analyzed some defuzzification methods for theoretical and practical advancements of fuzzy system. Kumar and Giri (2019) proposed an artificial neural network based model to get the job sequence that minimize the makespan for n job and m machine flow shop scheduling problem. Fitzpatrick et al.(2019) concluded that modelling involving the information from multiple medical and public health sources, such as microbiologists, immunologists and epidemiologist, would be most informative for public health planners in contemplating intervention strategies. Al-Hussein & Tahir (2020) developed a generalized SEIR model to simulate the ongoing spread of the disease and forecast the future behaviour of the outbreak. Kim et al. (2020) identify the pattern of local transmission of COVID-19 using mathematical modelling and predict the epidemic size and the timing of the end of the spread. Guan et al. (2020) revealed the spread rules of three pneumonia: COVID-19, SARS and MERS. Bhola et al. (2020) discussed a predictive mathematical model that can provide us some idea of the future of the virus. Prem et al.(2020) simulated the ongoing trajectory of an outbreak in Wuhan using an age-structured susceptible-exposed-infected-removed (SEIR) model for several physical distancing measures. Guan et al. (2020) discusses the importance of modelling in understanding COVID-19 spread. Nishiura et al.(2020) estimate the serial interval of novel COVID-19 from information on 28 infector-infected pairs. Lamba (2020) find the answer of the question Why India needs to extend the nationwide lockdown? Singh & Adhikari (2020) use an age-structured SIR model with social contact matrices obtained from surveys and Bayesian imputation to study the progress of the COVID-19 epidemic in India. Gros et al. (2020) introduce a modified epidemic model, the controlled-SIR model, in which the disease reproduction rate evolves dynamically in response to political and societal reactions. Gros (2020) propose a new mathematical model to predict the new cases or total infected cases in practical scenario. Streit et al.(2020) review to assess the effects of quarantine of individuals who had contact with confirmed cases of COVID-19. Kumar and Giri (2020) have developed a multi layer neural network based model for solving the flow shop scheduling problem to minimize the makespan. Kumar and Giri (2020) have proposed the fuzzy and neural network based approach and developed an algorithm for solving the flow shop scheduling problem.

The rest of the paper is organized as follows. In section 2, we describe the proposed neural network approach with algorithm and some precautions and preparedness to control COVID-19. We have also constructed the architecture diagram for model and preparedness under study in the same section. In section 3, computational results of five countries with graphical representation are explained. Also comparative level of COVID-19 infection risk according to population density/ km^2 of the countries are described. Finally in section 4, the paper ends with some conclusion and future work.

II. DESCRIPTION OF THE PROPOSED ARTIFICIAL NEURAL NETWORK BASED APPROACH:

Obtaining accurate information during an ongoing pandemic is extremely difficult when circumstances shift daily, as we have seen with the COVID-19 virus. How to control the outbreak of COVID-19 disease and ease the spreading of this infectious disease is an urgent issue facing the society at present. As COVID-19 spreads worldwide, decision makers believe on mathematical models to make public health and economic decisions. In the current study, we present a neural network based algorithm with lockdown condition which will enable us to forecast about the efficiency of different countries across the globe for checking the level of COVID-19 infection risk based on the previously confirmed cases recorded in any country. In this model, there are three hidden layers, one input layer and one output layer. In the input layer there are two input neurons, which are the numbers of COVID-19 patients in the starting two days in any country. There are three hidden layers in which l, m and n neurons exist respectively, where l. m. n are the number of COVID-19 patients in different l, m and n days. In this model between hidden layers the lockdown condition is applied to control the COVID-19 disease. The last layer is the output layer which gives the final output value. The architecture diagram of the developed neural network model is displayed in the following figure 1:

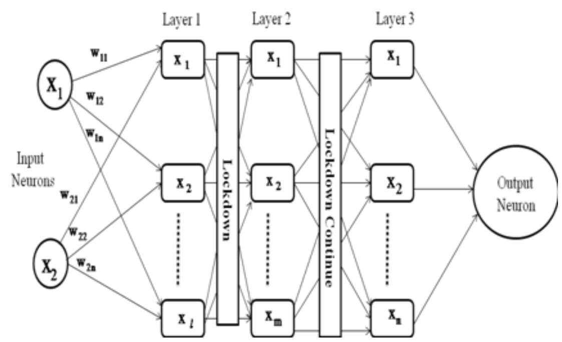

Figure 1: Architecture diagram of proposed neural network

There are some precautions and preparedness to control the COVID-19 disease, which are described as follows:

- nput: COVID-19 suspected cases of m
- days.
- ass these suspected cases through testing set and after completion of testing, divided theses cases in two category, One category is of positive symptoms patient set and the another category is of negative symptoms patient set.
- f symptoms of suspected patient are positive then quarantine them
- f symptoms of suspected patient are negative then discharge those patients
- ive the medical treatment to the patients who are quarantined.
- ockdown all the effected places of the country very strictly to break the change of COVID-19.
- se all the precautions as hand wash, wearing mask, sanitizer, social distancing etc
- ontinue the lock down until the number of COVID-19 patient case could not stop.

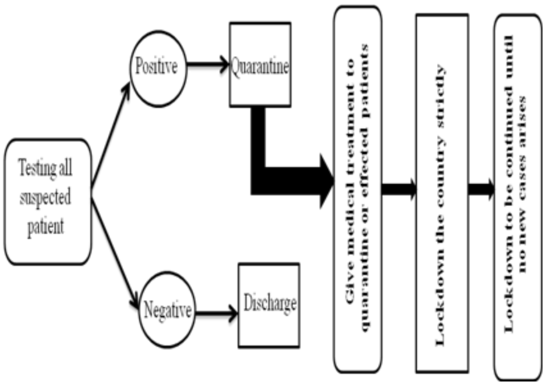

Figure 2: Work flow diagram of precautions and preparedness

The different steps involve in the working process of our proposed artificial neural network model in algorithm form is described as follows:

Algorithm:

Step1: x_1 and x_2 define the input to layer 1

Step2: Find the weights on the connection links by using the following weight function:

$$w_{ij} = \frac{1}{\text{Input value}}$$

Step3: Compute the input values for layer 1 by:

$$y_{inp1} = x_1 \cdot w_{11} + x_2 \cdot w_{21} = \sum_{i=1}^{2} x_i \cdot w_{i1}$$

Step4: Find the output value from layer 1 by using the following activation function:

$$O_1 = \frac{1}{1+(y_{inp1})}$$

Step5: Calculate the input value for the layer 2 by:

$$y_{inp2} = x_1 \cdot w_{12} + x_2 \cdot w_{22} + \ldots x_l \cdot w_{l2} = \sum_{i=1}^{l} x_i \cdot w_{i2}$$

Step6: Find the output value from layer 2 by:

$$O_2 = \frac{1}{1+(y_{inp2})}$$

Step7: Calculate the input value for the layer 3 by:

$$y_{inp3} = x_1 \cdot w_{13} + x_2 \cdot w_{23} + \ldots x_m \cdot w_{m3} = \sum_{i=1}^{m} x_i \cdot w_{i3}$$

Step8: Find the output value from layer 3 by:

$$O_3 = \frac{1}{1+(y_{inp3})}$$

Step9: Calculate the input value for the layer 4 by:

$$y_{inp4} = x_1 \cdot w_{14} + x_2 \cdot w_{24} + \ldots x_n \cdot w_{n4} = \sum_{i=1}^{n} x_i \cdot w_{i4}$$

Step10: Find the output value from the final output layer 4 by:

$$O_4 = \frac{1}{1+(y_{inp4})}$$

Step11: End

The final output value provides the level of COVID-19 infection risk which always lies in [0, 1]. Lower the output value means lower the COVID-19 infection risk and higher the output value means higher the COVID-19 infection risk. If for a particular country, level of COVID-19 infection risk is high then it is very dangerous and requires more strict policies and plans to control COVID-19. By finding the level of COVID-19 infection risk of different countries, one can find out which country is safe and which country is facing more problems due to COVID-19 infections.

III. IMPLEMENTATION

Example1. The number of active cases in India from the COVID-19 disease from 2 March to 08 May is given below in the following table 2.

Table 2: Number of COVID-19 infected cases in India

Date	Number of COVID-19 Active Cases	Date	Number of COVID-19 Active Cases
2 March	5	5 April	3577
3 March	6	6 April	4281
4 March	28	7 April	4789

5 March	30	8 April	5274
6 March	31	9 April	5865
7 March	34	10 April	6761
8 March	39	11 April	7529
9 March	44	12 April	8447
10 March	50	13 April	9352
11 March	60	14 April	10815
12 March	73	15 April	11933
13 March	81	16 April	12759
14 March	97	17 April	13835
15 March	107	18 April	14792
16 March	118	19 April	16116
17 March	137	20 April	17656
18 March	151	21 April	18985
19 March	173	22 April	20471
2 0 March	223	23 April	21700
2 1 March	283	24 April	23452
22 March	360	25April	24942
23 March	434	26 April	26917
24 March	519	27 April	29451
25 March	606	28 April	31324
26 March	694	29 April	33062
27 March	834	30 April	34863
2 8 March	918	1 May	37257
29 March	1024	2 May	39699
30 March	1251	3 May	42505
31 March	1397	4 May	46437
1 April	1834	5 May	49400
2 April	2069	6 May	52987
3 April	2547	7 May	56351
4 April	3072	8 May	59695

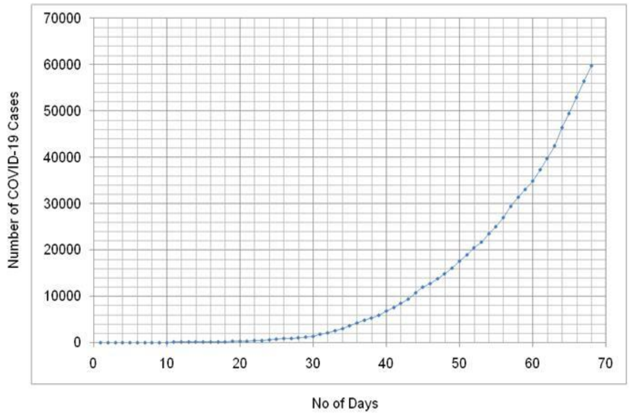

Figure 3: Number of COVID-19 infected cases Vs No. Of days

In the above mentioned table, the data before lockdown period is from 2 March to 22 March and the data of lockdown period is from 23 March to 08 May. The data dates for different layers are provided in the following table

Table 3: Data dates for different layers

S. No.	Layer	Data Dates
1.	Input layer	02 March-03 March
2.	First hidden layer	19 March-22 March
3.	Second hidden layer	01 April-06 April
4.	Third hidden layer	29 April-08 May

Now by applying the steps of proposed algorithm the input values are 5 and 6 and the weights on the connection links from input layer to first hidden layer are 0.2 and 0.167 respectively. By applying the step 3 of the algorithm, the input value from input layer to first hidden layer is $y_{inp1} = 2.002$ and after applying the step 4, the output value O_1 is 0.33311. The weights on the connection links from first hidden layer to second hidden layer are 0.00578, 0.00448, 0.00353 and 0.00277 respectively. By using the step 5 of the algorithm, the input value from first hidden layer to second hidden layer is $y_{inp2} = 3.99517$ and after applying the step 6, the output value O_2 is 0.20019. Now the weights on the connection links from second hidden layer to third hidden layer are 0.00054, 0.00048, 0.00039, 0.00032, 0.00027 and 0.00023 respectively. By applying the step 7 of the algorithm, the input value from second hidden layer to third hidden layer is $y_{inp3} = 5.91027$ and after applying the step 7, the output value O_3 is 0.14471. Now the weights on the connection links from third hidden layer to output layer are 0.00003024, 0.00002868, 0.00002684, 0.00002518, 0.00002352, 0.00002153, 0.00002024, 0.00001887, 0.00001774 and 0.00001675 respectively.

By applying the step 9 of the algorithm, the input value y_{inp4} from third hidden layer to output layer is 9.99804931 and after that applying the step 10 the output value O_4 is 0.090925215. Thus the level of COVID-19 infection risk for India is 0.090925215.

Example2. The number of active cases in USA, Italy, Spain and United Kingdom from the COVID-19 disease from 2 March to 08 May is given below in the following table 4.

Table 4: Number of COVID-19 infected cases in four countries

Date	USA	Italy	Spain	United Kingdom
2 March	100	2036	120	39
3 March	124	2502	165	51
4 March	158	3089	228	87
5 March	221	3858	282	116
6 March	319	4636	401	164
7 March	435	5883	525	209
8 March	541	7375	674	278
9 March	704	9172	1231	321
10 March	994	10149	1695	383
11 March	1301	12462	2277	460
12 March	1630	15113	3146	590
13 March	2183	17660	5232	798
14 March	2771	21157	6391	1140
15 March	3617	24747	7988	1391
16 March	4604	27980	9942	1543
17 March	6357	31506	11826	1950
18 March	9317	35713	14769	2626
19 March	13898	41035	18077	3269
2 0 March	19551	47021	21571	3983
2 1 March	24418	53578	25496	5018
22 March	33840	59138	28748	5683
23 March	44189	63927	35136	6650
24 March	55398	69176	42058	8077
25 March	68905	74386	49515	9529
26 March	86379	80589	57786	11658
27 March	105217	86498	65719	14543
2 8 March	124788	92472	73235	17089
29 March	144980	97689	80110	19522
30 March	168177	101739	87956	22141
31 March	193353	105792	95923	25150
1 April	220295	110574	104118	29474
2 April	250708	115242	112065	33718
3 April	283477	119827	119199	38168
4 April	317994	124632	126168	41403
5 April	343747	128948	131646	47806
6 April	375348	132547	136675	51608
7 April	409225	135586	141942	55242
8 April	441569	139422	148220	60733
9 April	475515	143626	153222	65077
10 April	509604	147577	158273	73758
11 April	539942	152271	163027	78991
12 April	567708	156163	166831	82279
13 April	594693	159516	170099	88621
14 April	621953	162488	174060	93873
15 April	652474	165155	180659	98476
16 April	682454	168941	184946	103093
17 April	714822	172434	190839	108692
18 April	743901	175925	194416	114217

19 April	770014	178972	198674	120067
20 April	798145	181228	200210	124743
21 April	824229	183957	204178	129044
22 April	854385	187327	208389	133495
23 April	886274	189973	213024	138078
24 April	925232	192994	209764	143464
25April	960651	195351	223759	148377
26 April	987160	197675	226629	152840
27 April	1010356	199414	229422	157149
28 April	1035765	201505	232128	161145
29 April	1064194	203591	236899	165221
30 April	1095023	205463	239340	171253
1 May	1131030	207428	242979	177454
2 May	1160774	209328	245589	182260
3 May	1188122	210717	247122	186599
4 May	1212835	211938	248301	190584
5 May	1237633	213013	250561	194990
6 May	1263092	214457	253681	210101
7 May	1292623	215858	256855	206715
8 May	1321785	217185	260117	211364

From the data of above mentioned four countries and by applying the proposed neural network algorithm the output values of the countries is displayed in the following table 5.

Table 5: Outputs by proposed model algorithm of different five countries

S. No.	Country	Data date	Level of COVID-19 infection risk
1	India	2 March-30 April	0.090925215
2	USA	2 March-30 April	0.094942317
3	Italy	2 March-30 April	0.092771036
4	Spain	2 March-30 April	0.092983172
5	United Kingdom	2 March-30 April	0.091975423

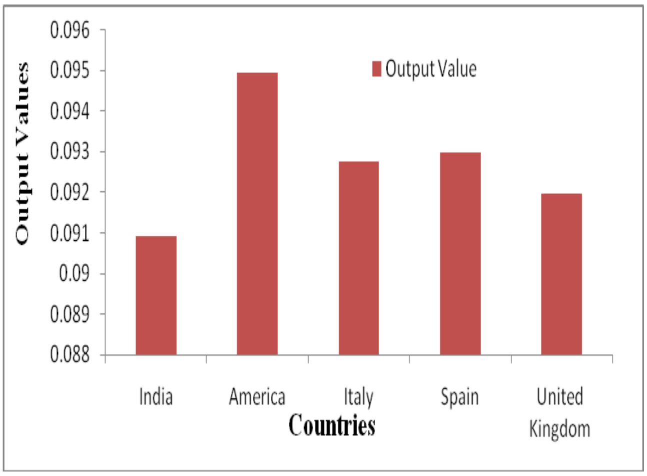

Figure 4: Graphical representation of the results

The results are also depicted in figure 4. The results show that at present, India has minimum COVID-19 infection risk in comparison of other four countries. Hence from the results it is very clear that in India, lockdown has been very effective to break the chain of COVID-19 disease in comparison of other four countries.

Comparative level of COVID-19 infection risk according to population density/ km^2

Across the world, COVID-19 has taken root and hit hard in several types of places and countries. Population density is likely just one of a number of key factors that determine how vulnerable places are to the virus. Population density is a main factor in spreading of COVID-19 pandemic. If there is r numbers of countries considered for the COVID-19 study, then the comparative level of COVID-19 infection risk with respect to population density/ km^2 is obtained by using following formula:

Comparative level of COVID-19 infection risk for i-th country = $\frac{1}{1+(y_{inp4})}\cdot\left[1-\frac{D_i}{\sum_{i=1}^{r} D_i}\right]$

where D_i is the population density for the i-th country

The population density of five countries is given below in the following table 6.

Table 6: Population density of five countries

S. No	Country	Population Density/ Km^2
1.	India	460
2.	USA	36
3.	Italy	206
4.	Spain	94
5.	United Kingdom	274

The comparative level of COVID-19 infection risk for each considered countries are given in the following table 7.

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Table 7: Comparative level of COVID-19 infection risk for different five countries

S. No	Country	Comparative level of COVID-19 infection risk
1	India	0.051835870
2	USA	0.091747996
3	Italy	0.074910444
4	Spain	0.084814556
5	United Kingdom	0.068422838

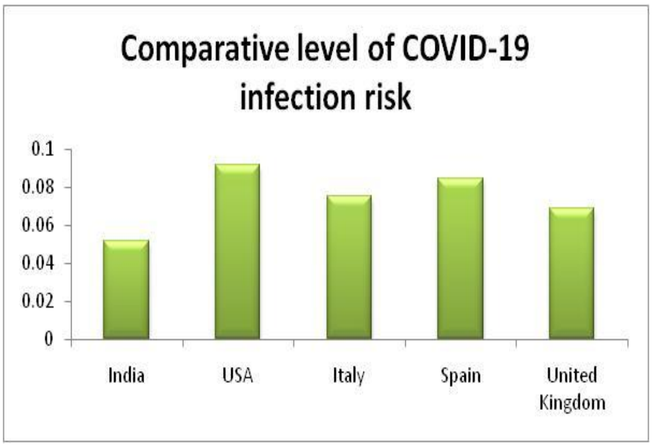

Figure 5: Graphical representation of comparative level of COVID-19 infection risk

Table 7 and figure 5 show that India has less COVID-19 infection risk among the five countries even though the population density/ km^2 of India is maximum. This time USA has highest COVID-19 infection risk. Thus India has control the spreading of COVID-19 epidemic more efficiently in comparisons of other four countries due to timely lockdown the country very strictly. This shows that effective implementation of lookdown is a preventive measure in controlling of COVID-19 infection disease. Hence until the vaccine is not invented for COVID-19, lockdown is the best solution to control the spreading of this disease.

IV. CONCLUSION AND FUTURE SCOPE:

The artificial neural network technique has been effectively applied for solving real world problems. In this paper an artificial neural network based model has been developed for finding the level of COVID-19 infection risk. In this paper, a multilayer neural network based approach involving lockdown condition between hidden layers has been developed for calculating the level of COVID-19 infection risk by using the previously confirmed cases (up to 8 May-2020) recorded in any country. Also comparative levels of COVID-19 infection risk based on population density are also obtained for five major infected countries. From the outcomes of the different countries data results, it is clear that at present timely lockdown is the best solution to control the spreading of COVID-19 infection. As a further study, the present neural network model can be extended and modified for future study. Different type's neural networks models can develop for calculating the other performance measures related to COVID-19.

Conflict of interest: On behalf of all authors, the corresponding author states that there is no conflict of interest.

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