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A novel COVID-19 infection-forecasting model based on artificial neural networks

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A B S T R A C T

The COVID-19 surge has mostly affected people and wreaked havoc on multiple sectors of the global economy. This study uses artificial neural networks (ANN) to develop COVID-19 prediction models to minimize the perilous situation. With positive infection data, these hybrid artificial neural network models looked at COVID-19 cases in Andhra Pradesh, India. Then, COVID-19 data were divided into training and testing for simulation. The developed model that takes the previous 14 days into account outperforms the others, depending on the results. According to the developed ANN models for Andhra Pradesh districts, the prediction model that works well and yields positive results is the one that receives lower values of error metrics like MSE, RMSE, MAE, and MAPE and higher values of R^2. The hybrid neural network model that considers the previous 14 days for prophecy has suggested anticipating daily positive suffering, notably in areas of Andhra Pradesh, as a result of the collected data. Linear regression, ARIMA, and LSTM have been used for model assessment. The proposed 14-day model statistically surpasses all metrics in RMSE, MAE, MAPE, and R^2. This study showed that an ANN-based model can predict the COVID-19 outbreak as well as other epidemics.

1. Introduction

The COVID-19 also referred to as coronavirus or SARS-CoV-2, is a highly transmissible disease that has rapidly spread across the globe and it becomes the most dangerous disease all over the World. Coronavirus has a vast background and it has existed with numerous labels, including Middle East Respiratory Syndrome Coronavirus (MERS-CoV), Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV), and so on. Moreover, SARS-COV-2 is indeed detected as a coronavirus with a substantial increase in human-to-human propagation (Niazkar et al., 2020). Coronavirus, like the flu, is a highly transmissible and pathogenic virus with patterns of development and these forms are quasi-unpredictable in nature (Sevak et al., 2018). The first variant of the coronavirus infected people from civet cats in China in 2002, as well as the second version of COVID-19, disseminated from camels to humans in Saudi Arabia in 2012 (Hamadneh, Khan, et al., 2021). Following its detection in Wuhan, China in December 2019, World Health Organization (WHO) proclaimed it a global chronic condition in January 2020, and it became a global epidemic (Singhal, 2020). As the epidemic is recognised to be disseminated solely via gasping channels, medical authorities have undertaken precautionary measures in many nations, including travel restrictions, quarantines, partial lockdowns, and sanitizations (Niazkar & Medicine, 2020). Despite the fact that there is a lack of awareness of the ailment and also that no medication was being introduced, Owing to this, people's daily lifestyles have been disrupted, institutions, industries, and markets are being impacted, and governments are taking effective steps to avoid the diffusion of COVID-19 (Ahmad & Asad, 2020). Since December 2019, the COVID-19 cases that occurred worldwide totalled more than

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19 crores, and 14 lakhs were deceased (*COVID Live - Coronavirus Statistics - Worldometer*, 2021.). In general, Andhra Pradesh has occurred more than 19lakhs were infected through COVID-19 and 13000 thousand were departed (*COVID-19 : Andhra Pradesh Department of Health, Medical, & Family Welfare,* 2021.). COVID-19 had mostly infected people between the ages of 20 and 45. People with medical challenges such as high blood pressure, diabetes, and other ailments have more exposed to this condition. Because of a lack of immunity in their bodies, they were irresponsible and disobeyed the COVID-19 safety precaution regulations. A number of Indian states are suffering monetarily as a consequence of the epidemic, with Andhra Pradesh being the worst affected. The positive thing that occurred in Andhra Pradesh was 19lakhs of people have healed from COVID-19. The main reason behind the plague is human dissemination.

According to recent investigations, mathematical, statistical, and machine learning methods have implemented to assess infections of epidemics. For instance, Nouvellet et al. (2018) suggest mathematical techniques to understand viral transmission. Statistical techniques were carried out by Nishiura et al. (Nishiura et al., 2020) to assess the COVID-19 infections among Japanese travellers. To estimate the R-value of coronavirus in a ship, Zhang et al. (2020) have devised statistical models including gamma and poison distributions in 2020. Pal et al. (2020) exploited LSTM networks and Bayesian optimization to investigate the COVID-19 potential risks on a country-by-country basis. To simulate the COVID-19 cases in seven nations, Niazkar and Niazkar (2020) developed forecasting models based on artificial neural networks. To protect Bangladesh from new COVID-19 infections, Zisad et al. (2021) used a combination of neural networks and Susceptible, Exposed, Infected, Removed (SEIR) model. With the help of neural networks and prey-predator techniques, Hamadneh et al. (Hamadneh, Tahir, et al., 2021) build a prediction model for diagnosing COVID-19 cases in Mexico and Brazil. For simulating the COVID-19, Roosa et al. (Roosa et al., 2020) presented three kinds of estimation methods: Richards, logistic, and a sub-epidemic wave model. The adaptive neuro-fuzzy inference system (ANFIS) is a method that uses neural networks with fuzzy logic to make non-linear predictions. Jithendra and SS (2022) applied this strategy to forecast the COVID-19 outbreak. With the incorporation of meta-heuristic optimization techniques into ANFIS, Al-Qaness et al. (Al-Qaness et al., 2020) devised an improved prediction model for COVID-19. For identifying the future COVID-19 cases, Namasudra et al. (2021) built a non-linear regression neural network system with different optimization approaches. Wieczorek et al. (2020) employed artificial neural networks (ANN) and recurrent neural networks (RNN) to study the COVID-19 cases, finding that RNN outperforms ANN in predictive performance. To investigate the COVID-19 cases in six different nations, Tamang et al. (2020) introduced a neural network-curve fitting approach. By our perceptions, hybrid neural networks models are limited in their ability to predict the COVID-19 outburst. This study focused to estimate the prediction of positive cases by using ANN models with backpropagation algorithm and gradient descent approach to regulate the weights of connections. The recommended technique has been evaluated on the COVID-19 dataset from Andhra Pradesh, India, because COVID-19 is the most significant and widespread problem that people are currently facing. Pertaining to our findings, the sigmoidal function is considered an activation function in ANN, which surpasses other activation functions such as the linear, binary step, and bipolar sigmoid functions. The sigmoidal function performed the best at predicting positive cases and exhibited the lowest RMSE, MAE and MAPE values across all the datasets in Andhra Pradesh. The goal of this report is to improve the predictive performance of the presented model for reported infections. To validate the effectiveness of the ANN model, the authors compare it to a variety of competing techniques, such as linear regression, ARIMA, and LSTM. Based on the comparative analysis, the authors discovered that fourteen ANN-based models were successful at predicting the outbreak of the plague in thirteen Andhra Pradesh districts. Moreover, these models can help governments to foresee the allotment of medical resources, build a state of readiness for medical organizations and will assist in progressively regenerating the economy.

The work is organised into the following sections: Section 2 highlights an overview of the artificial neural networks with backpropagation algorithms. The simulation results are highlighted in Section 3, along with graphical outputs and comparison analyses. The discussion and findings are presented in Section 4, and the conclusion, final thoughts, and suggestions for further research are provided in Section 5.

2. Methodology

This study has devised to bid ANN predict positive cases of COVID-19 plague taking two to fourteen days as the isolated time. In this regard, positive cases in districts of Andhra Pradesh were utilized in this study. Many states have affected by COVID-19 in India, but in Andhra Pradesh day to day, positive cases are raised rapidly. A few states have been infected through COVID-19 for a longer period in India; one of the states is Andhra Pradesh. The relevant data collected for the state of Andhra Pradesh can be split into the training part and testing parts. In training, data was used to execute the neural network models; whereas, in testing, data was used for differentiation. Consequently, the predicted and actual positive sufferers of test data were contrasted.

2.1 ANN development with backpropagation technique

Neural networks are an artificial intelligence (AI) model that is being inspired by the structure of human biological nerve cells. It has been used to resolve computational complications in a variety of fields. The intrinsic nature is, it is a high-powered tool for obtaining interconnections between the input and output layers. Accordingly, it required a several inputs and output values. The training method followed by the architecture of ANN is comprised of three layers: (i) input layer, (ii) hidden layer, and (iii) output layer. The input layer contains the neurons with input data and the output layer has a neuron with output, but the input layer does not perform any computations and simply transfers the input information to the hidden layer. The neurons in the hidden layer are interconnected with both input and output layers and perform the computations then convert them into outputs. Furthermore, they transfer a weighted sum of inputs using an activation function. The data passes across the layers of network retains up to with accurate results acquired. Eventually, the satisfactory ANN is trained; the more explicit outcomes may be accomplished. The research used MATLAB to train an ANN using a feed-forward backpropagation network with the gradient descent method technique. The gradient descent method's algorithm for weights updation is described as below:

$$w_{k+1} = w_k + \nabla w_k \tag{1}$$

Here $\nabla w_k = -\eta \frac{\partial E}{\partial w_k}$ and $E = \frac{1}{2}\sum_{i=1}^{n}(actual_i - predicted_i)^2$

Finally, the updation formula for weights as follows

$$w_{k+1} = w_k - \eta \frac{\partial E}{\partial w_k} \tag{2}$$

The pseudo code representation of gradient descent optimization technique is as follows:

Algorithm : Pseudo Code of Gradient Descent Optimization

Input : $h : \mathbb{R}^n \rightarrow \mathbb{R}$ be a analytical function

$w^{(0)}$ be an initial solution

Output: y be a local minimum of the error function h.

begin

$k \leftarrow 0;$

While STOP and $\left(k < k_{\max}\right)$ **do**

$w^{(k+1)} \leftarrow w^{(k)} + \nabla w^{(k)}$;

With $\nabla w^{(k)} = -\eta \frac{\partial h}{\partial w^{(k)}}$;

$k \leftarrow k+1$;

return $w^{(k)}$

end

Regarding research, fourteen hybrids ANN models build for predicting the daily positive cases but five to fourteen models give the best performances and are recapitulated in Table1. In table1, s_j denotes the jth function (j = 5, 6, 7,..., 14) that Neural Network had to guess, and p_r denotes the number of everyday positive sufferers at time t. Regarding, models presented in Table 1, s_j is used to anticipate the COVID-19 outburst in the future. In the input, hidden, and output layers of the neural network used to obtain s_j there are one, three, and one neuron, respectively. Because the 14th replica proposed in Table 1 uses the everyday positive sufferers from the preceding fourteen days, the first sixteen inputs of data are excluded from the total data to allow training of all neural network models. As a consequence, the COVID-19 plague data that had been adopted were separated as (i) execution data (44 days) and (ii) comparison data (16 days). The Earlier utilized to execute neural network, even though it was used to evaluate how well neural network replicas anticipated the outburst of COVID-19.

Table 1
Five to fourteen hybrid ANN models to forecast the COVID-19 outburst

Models	**Equations**
Fifth model	$p_r = s_5 (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5})$
Sixth model	$p_r = s_6 (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5}, p_{r-6})$
Seventh model	$p_r = s_7 (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5}, p_{r-6}, p_{r-7})$
Eighth model	$p_r = s_8 (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5}, p_{r-6}, p_{r-7}, p_{r-8})$
Ninth model	$p_r = s_9 (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5}, p_{r-6}, p_{r-7}, p_{r-8}, p_{r-9})$
Tenth model	$p_r = s_{10} (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5}, p_{r-6}, p_{r-7}, p_{r-8}, p_{r-9}, p_{r-10})$
Eleventh model	$p_r = s_{11} (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5}, p_{r-6}, p_{r-7}, p_{r-8}, p_{r-9}, p_{r-10}, p_{r-11})$
Twelfth model	$p_r = s_{12} (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5}, p_{r-6}, p_{r-7}, p_{r-8}, p_{r-9}, p_{r-10}, p_{r-11}, p_{r-12})$
Thirteenth model	$p_r = s_{13} (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5}, p_{r-6}, p_{r-7}, p_{r-8}, p_{r-9}, p_{r-10}, p_{r-11}, p_{r-12}, p_{r-13})$
Fourteenth model	$p_r = s_{14} (p_{r-1}, p_{r-2}, p_{r-3}, p_{r-4}, p_{r-5}, p_{r-6}, p_{r-7}, p_{r-8}, p_{r-9}, p_{r-10}, p_{r-11}, p_{r-12}, p_{r-13}, p_{r-14})$

For effective illumination, a simplified outlook of the 3rd neural network is demonstrated as:

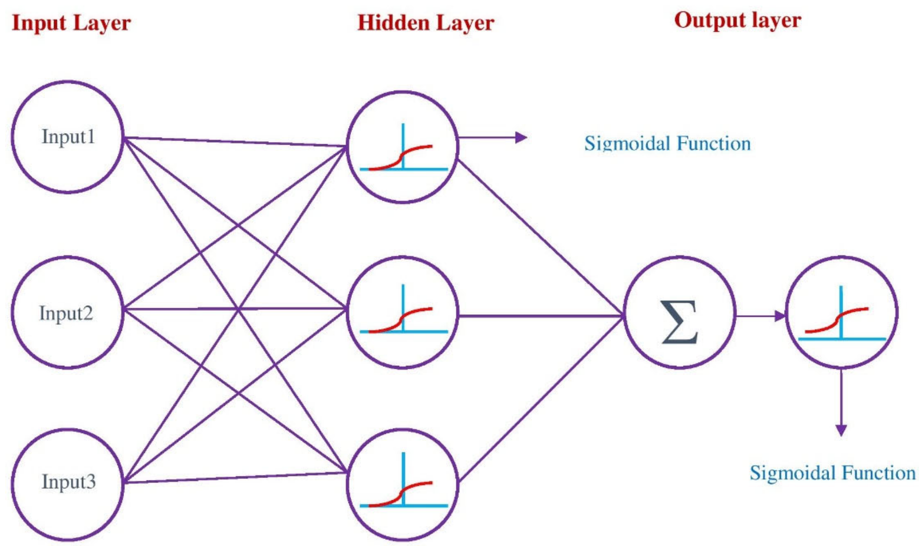


Fig. 1. Diagrammatic look of the 3rd neural network

2.2 Data Collection

Sequential data of positive cases of Covid-19 were cumulated from the Department of Health, Medical, and Family Welfare of the Government of Andhra Pradesh (*COVID-19 : Andhra Pradesh Department of Health, Medical, & Family Welfare, 2021*). When there was a high discrepancy among the data sources, so Chittoor was preferred. Between January 1 and January 8, 2021, both trained and tested confirmed samples occurred in Chittoor, resulting in expeditors increase in data collected. As part of the study, positive cases of districts of Andhra Pradesh have considered.

2.3 Data Interpretation

The interpretation of cumulated data has taken using MS-Excel, which provides vigorous possibilities for interpretation and executing analytical techniques. The consequences of this analysis and the data intervals used for all districts are enumerated below.

Table 2
Statistical analysis of the positive cases of COVID-19 in districts of Andhra Pradesh

Districts	Data interval in year 2021	Mean	Median	Standard deviation	MSE
Anantapur	01 January to 1 March	6.1335	5	5.5777	68.6832
Chittoor	01 January to 1 March	19.4084	16	13.4369	556.9550
East Godavari	01 January to 1 March	11.9037	11	7.8421	203.1025
Guntur	01 January to 1 March	14.6087	12	11.0618	335.5870
Kadapa	01 January to 1 March	5.9146	5	4.5426	55.5854
Krishna	01 January to 1 March	18.0373	15	12.5066	481.5155
Kurnool	01 January to 1 March	4.9643	4	4.9250	48.8618
Nellore	01 January to 1 March	5.8137	6	4.0582	50.2422
Prakasam	01 January to 1 March	3.0839	2	3.0311	18.6957
Srikakulam	01 January to 1 March	4.0435	3	2.9838	25.2329
Visakhapatnam	01 January to 1 March	13.8975	12	7.9651	256.4845
Vizianagaram	01 January to 1 March	2.1568	1	2.4858	10.8214
West Godavari	01 January to 1 March	7.1087	5	7.2193	102.5714

Following the standard deviation and mean squared error, the evidence from Chittoor, Krishna, and Guntur get a wider spread than those from other cities, as shown in Table 2. Fig. 2 represents the positive cases occurred during the month of January 2021 and Fig.3 depicts the positive cases transpired throughout the month February 2021 in Andhra Pradesh. Additionally, it has conspicuous variations in the daily positive cases of Andhra Pradesh. The broad spread and alterations in data necessitate the use of a powerful tackle to forecast the COVID-19 outburst. Hamid Reza Niazkar and Majid Niazkar utilized three-dimensional criteria to assess the execution of neural network replicas in forecasting the breakout of COVID-19. As part of our study, the following statistical metrics have employed: (i) Mean Squared Error (MSE), (ii) Root Mean Square Error, (iii) Mean Absolute Error, (iv) Mean Absolute Percentage Error (MAPE) and Determination Coefficient (R^2).

$$MSE = \frac{1}{N}\sum_{j=1}^{N}\left[p_{j,\,actual} - p_{j,\,predicted} \right]^2 \tag{3}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{j=1}^{N}\left(p_{j,\,actual} - p_{j,\,predicted} \right)^2} \tag{4}$$

$$MAE = \frac{1}{N}\sum_{j=1}^{N}\left| p_{j,\,actual} - p_{j,\,predicted} \right| \tag{5}$$

$$MAPE = \frac{100}{N}\sum_{j=1}^{N}\left| \frac{p_{j,\,actual} - p_{j,\,predicted}}{p_{j,\,actual}} \right| \tag{6}$$

$$R^2 = 1 - \frac{\sum_{j=1}^{N}\left(p_{j,\,actual} - p_{j,\,predicted} \right)^2}{\sum_{j=1}^{N}\left(p_{j,\,actual} - \overline{p}_{j,\,actual} \right)^2} \tag{7}$$

where $p_{j,\,actual}$, and $p_{j,\,predicted}$ are the jth actual and predicted values of day to day positive sufferers, individually and j is the number of days (j= 1,2,…N), and N denotes the total number of data sets. Accordingly, Eq. (3) and Eq. (6), forecasting models execute precisely as MSE and MAPE values decrease.

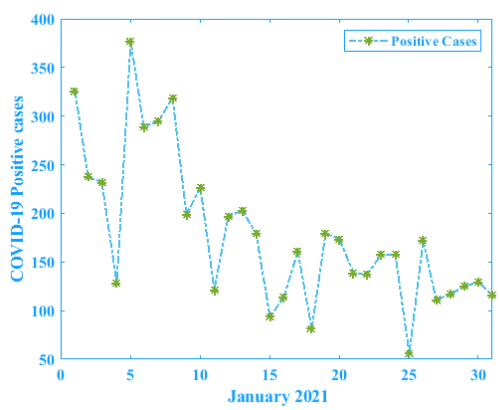


Fig. 2. Positive cases in Andhra Pradesh during the month of January 2021.

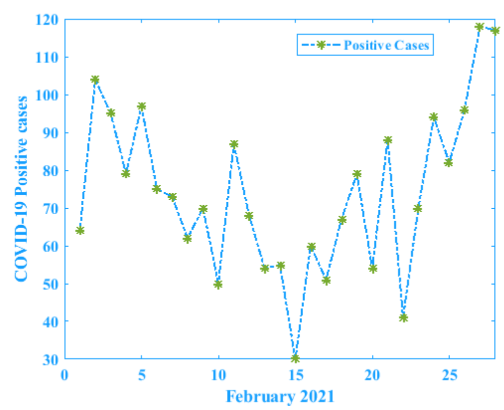


Fig. 3. Positive cases in Andhra Pradesh during the month of February 2021.

3. Results

Following ANN's training, the recommended replicas have utilized to forecast COVID-19 positive sufferers on a daily basis in districts of Andhra Pradesh. Fig. 4 represents the values of MSE and MAPE calculated by the neural network models in forecasting the COVID-19 outburst across the five major districts of Andhra Pradesh that is most affected when compared to other districts. As can be seen, the recommended neural networks are executed in a number of ways. Furthermore, only using positive sufferers from the day earlier to estimate daily positive cases by 1st, 2nd, 3rd, and 4th ANN-based models doesn't quite result in estimates for the major five districts studied.

To ascertain the two foremost ANN-based models, the system of rankings with each precision measure has the same weight that was derived from studies (Anam et al., 2021), every neural network replicas as well as, was used to assess. Such an arrangement distinguishes between exemplary that perform well and those that underperform. Depending upon these, every semantic network is listed first in observing with their MSE and MAPE values. Following that, the sum of two ranking values has computed and used as a new standard for ranking the competence of every neural network for every district. Table 3 represents the complete results of implementing this ranking system to five major districts in Andhra Pradesh. The lesser rank of a model represents more reliability in performance.

Based on the rankings in Table 3, the neural networks based on the foremost rank were selected, and their real cases were compared with the projected cases of the proposed model shown in Fig. 5, as well as correlated estimations versus the real ones in Fig. 6 for five districts for which comparison data was collected. In Fig. 6, instead, every plot depicts its actual against anticipated data everyday positive sufferers. In this case, the closer dot is to the curve of connection, the closer the forecasted value is to the actual. Furthermore, the dot is situated away from the target; the slighter precisely the forecasted number of positive sufferers. The comprehensive attained results represent individually for five major districts of Andhra Pradesh as pursues:

Table 3
Illustrates the ranking the semantic network replicas for anticipating positive sufferers of comparison data

Models	Rankings				
	Chittoor	Krishna	Guntur	Visakhapatnam	East Godavari
1st model	12	13	12	14	11
2nd model	14	12	11	11	13
3rd model	11	14	13	12	14
4th model	13	11	14	13	12
5th model	3	4	6	10	9
6th model	10	5	8	5	1
7th model	2	8	7	1	2
8th model	6	6	9	2	5
9th model	8	7	10	3	3
10th model	5	9	3	8	7
11th model	7	10	4	6	4
12th model	1	3	5	7	8
13th model	4	1	2	9	6
14th model	9	2	1	4	10

- Anticipating novel *coronavirus* disease 2019 surge in Chittoor:

Executions of the semantic networks for Chittoor from 13 February to 1 March 2021 with their error metric values have shown in Fig. 4(i). According to Table 3, the 12th, 7th, 5th, 13th, and 10th models attain nearer positive sufferers to the actual sufferers of Chittoor when contrasted to other neural networks. The 12th ANN model outperforms other models and forecasted cases as compared with actual cases as visualised in Fig. 5 (i). Despite the fact that the anticipatory outcomes of any forecasting model are associated with marginal flaws, the recommended network replicas foresee the number of day-to-day positive COVID-19 sufferers dense towards the actual sufferers. All such precise forecasts are reassuring in light of the fact that the time-related changes of everyday positive cases depicted in Figs. 1 and 2 exemplify consequential undulations.
Furthermore, in Chittoor, the interval of estimation of positive sufferers is through the earliest wave of the outburst of COVID-19. It further assists neural networks replicas to execute correctly because it allows them to be in close association with the trend of the breakout in the execution data. Accordingly, the recommended semantic networks are proposed to forecast positive sufferers even before the first wave of the COVID-19 breakout is accomplished there in execution samples.

- Anticipating novel *coronavirus* disease 2019 surge in Krishna:

Krishna is one of the premature districts grievously affect by COVID-19. When compared to other replicas, Table 3 represents that the 13th hybrid neural network is the finest for forecasting COVID-19 in the Krishna district. Consequently, the 14th, 12th, 5th, and 6th models also gave accurate results. Fig. 6(ii) represents the disparity between the actual cases and predicted cases. Fig. 4(ii) illustrates the comparative analysis of MSE and MAPE values. After summing up the MSE and MAPE values that model gets a lower value, that model has the greatest performance. Furthermore, the actual cases versus anticipated cases of the 13th ANN model has depicted in Fig. 5 (ii). As seen in Fig. 6(ii), the preponderance of the points is under the impartiality of lineament. It reveals also that semantic networks overestimated the everyday positive COVID-19 sufferers in Krishna from 13 February to 1 March 2021. The performance of the network for the Krishna district has taken the 7698 number of iterations for best execution based on mean squared error.

- Anticipating novel *coronavirus* disease 2019 surge in Guntur:

Guntur has accomplished comparatively plentiful positive cases of COVID-19 among different districts of Andhra Pradesh. In Fig. 4(iii), the execution performances of various semantic networks for forecasting the positive sufferers of Krishna has analogized. The comparison of actual and predicted cases has shown in Fig. 6(iii). In Table 2, the 14th model is the best ANN-based model for the Guntur district, and its estimated cases have compared to actual cases in Fig. 5 (iii). This model gives reliable results with more accuracy. Similarly, the 13th and 10th models also performed accurately with good predictions.

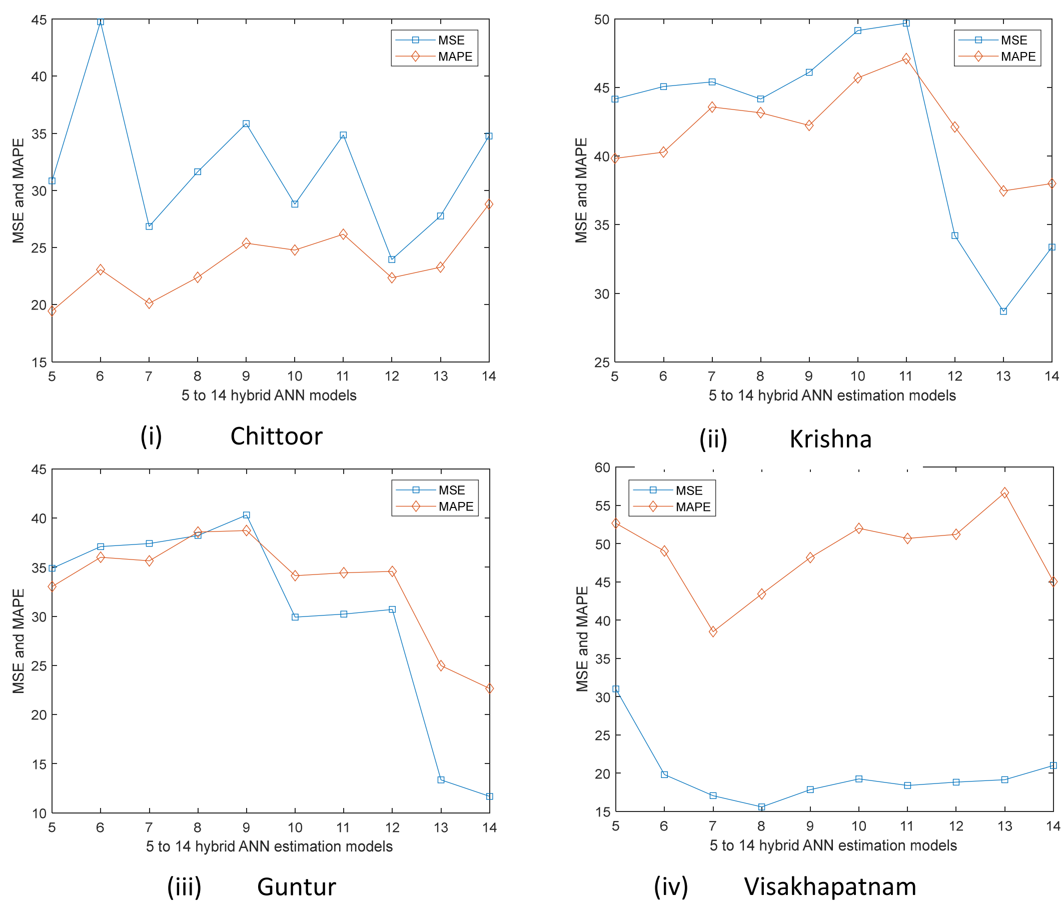
- Anticipating novel *coronavirus* disease 2019 surge in Visakhapatnam:

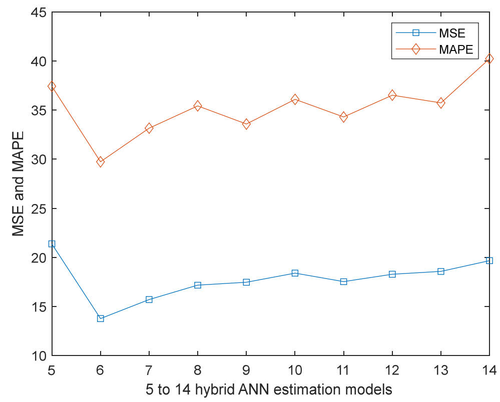
According to Table 2, the 7th, 8th, and 9th semantic networks used in forecasting the breakout of COVID-19 in Visakhapatnam have great executions. The positive cases were estimated with the greatest accuracy using the 7th ANN model, as shown in Fig. 5(iv). The similarities between the MSE and MAPE of 5 to 14 ANN models have represented in Fig. 4(iv). The positive cases utilized for the Visakhapatnam designates that the data is decreasing continuously. It implicates highest of the execution data is much less than the comparison data's optimum. It might result in MSE and MAPE values that are significantly greater than those required in other districts. For this cause, the ANN models have given unsatisfactory performances for Visakhapatnam.

- Anticipating novel *coronavirus* disease 2019 surge in East Godavari:

The execution performance of the semantic networks in anticipating the day-to-day positive sufferers of East Godavari is represented in Fig. 4(v), which shows the comparative analysis of MSE and MAPE in East Godavari for 5 to 14 models. Following Table 2, the 6th, 7th, and 9th ANN models have the finest execution and produce accurate estimations have presented in Fig. 5 (v). According to Fig. 3, the positive cases are slightly decreasing; the lower daily confirmed positive cases in East Godavari are as high in comparison data. This generally, produces a neural network (NN) with insufficient comparison data, allowing numerous semantic networks to anticipate acceptable predictions.

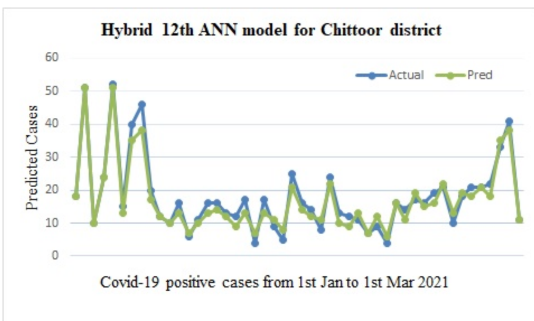
Eventually, the finest hybrid ANN models for five districts Chittoor, Krishna, Guntur, Visakhapatnam, and East Godavari are 12th, 13th, 14th, 7th, and 6th respectively. This study measured the effectiveness of these models by contrasting them with well-established methods, including linear regression, ARIMA, and LSTM. This was achieved by comparing statistical tools including RMSE, MAE, MAPE, and R^2. A summary of the results against alternative techniques can be found in Table 4. The research concluded by stating that the ANN model surpasses the other approaches, namely linear regression, ARIMA, and LSTM, with the lowest RMSE, MAE, MAPE, and the highest R^2 value.



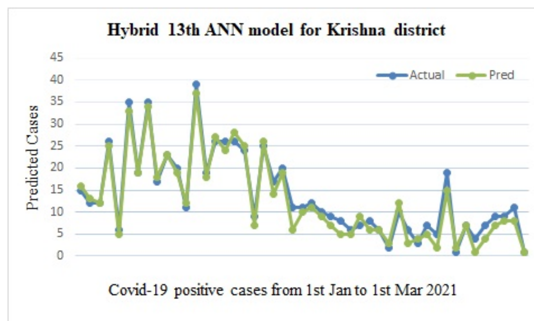


(v) East Godavari

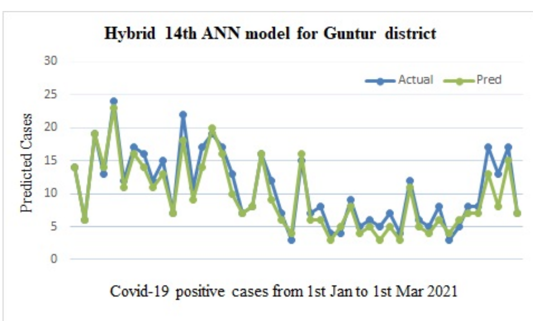
Fig. 4. Graphical comparative analysis of MSE and MAPE utilizing ANN-based models



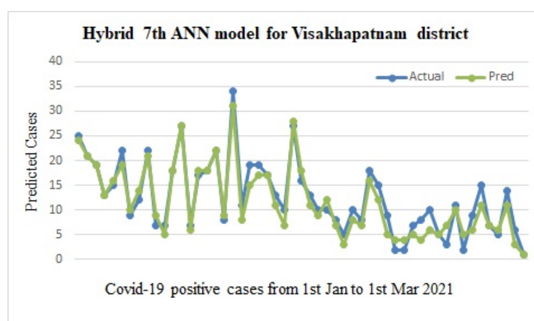
(i) Chittoor



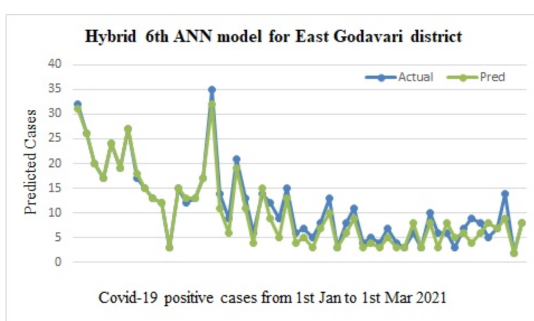
(ii) Krishna



(iii) Guntur



(iv) Visakhapatnam



(v) East Godavari

Fig. 5. Represents the Actual cases vs. Predicted cases for the best models of five districts

Table 4
Comparative analysis of statistical measures

Districts	Prediction Model	RMSE	MAE	MAPE	R^2
Chittoor	Linear Regression	5.0189	3.9382	0.4278	0.9301
	ARIMA	5.8261	4.1810	0.6741	0.9198
	LSTM	2.7408	2.4078	0.1682	0.9406
	ANN	**2.3418**	**1.8041**	**0.1318**	**0.9669**
Krishna	Linear Regression	4.0342	3.8673	0.3991	0.9395
	ARIMA	4.1093	3.7781	0.3818	0.9221
	LSTM	1.8989	1.6371	0.2745	0.9593
	ANN	**1.5962**	**1.2531**	**0.1834**	**0.9781**
Guntur	Linear Regression	6.1163	5.7219	0.5593	0.9004
	ARIMA	3.9698	3.0168	0.3352	0.9291
	LSTM	3.8132	2.5702	0.2183	0.9299
	ANN	**3.4445**	**2.0478**	**0.1880**	**0.9384**
Visakhapatnam	Linear Regression	4.9712	4.4148	0.4044	0.9156
	ARIMA	3.9941	3.1836	0.3013	0.9260
	LSTM	2.2272	2.0060	0.2749	0.9333
	ANN	**1.9044**	**1.4358**	**0.1977**	**0.9501**
East Godavari	Linear Regression	4.0029	3.6028	0.3477	0.9308
	ARIMA	2.9145	2.3383	0.2998	0.9398
	LSTM	2.4501	2.1192	0.2819	0.9557
	ANN	**1.5196**	**1.0888**	**0.1722**	**0.9698**

4. Discussions

As formerly recommended, Neural Network (NN) was used in this study to anticipate everyday positive COVID-19 sufferers. One and foremost, when used for forecasting within the scope of executed data, NN typically anticipates the finest. Forecasting the upcoming number of positive sufferers, in particular, naturally incorporates time values outside of the execution data's span. Specifically, the use of a neural network (NN) may be appropriate for quick forecasting, all these as the many steps ahead. Furthermore, quick forecasting doesn't supply an appropriate view of the COVID-19 outburst for medical management is to make decisions, neural network (NN) is often make use of as a statistical forecasting tool, such an application necessitates a huge data for the neural network (NN) to catch feasible structures. Additionally, a quite dataset is unavailable for COVID-19 during this period. All such imperfections might well enclose the implementation of neural networks (NN) as forecasting the COVID-19 outburst, despite research recommended semantic neural networks for this reason. Following the use of 14 semantic network replicas toward forecast, the COVID-19 outburst over thirteen districts of Andhra Pradesh, the values of MSE and MAPE were used to compute lesser values of two measures for all 5th to 14th models in five major districts. Fig. 4 shows the MSE and MAPE values for five major districts in Andhra Pradesh, with the best moderate values of mean absolute percentage error and mean squared error in the case of Guntur, 34.33, and the greatest moderate values of mean absolute percentage error and mean squared error in the case of Krishna, 96.80. This distinctly specifies taken only one measure may not be limited to evaluate the execution of forecasting findings, while various measures will provide a more precise picture of the results' accuracy. In comparison to Fig. 4, the all-inclusive execution of semantic neural networks in the cases of Chittoor, Krishna, Guntur, Visakhapatnam, and East Godavari is ranked 12th, 13th, 14th, 7th, and 6th, respectively, and their performance convergence can be seen in Fig. 7.

According to Table 3, the seventh replica took first place in the ranking system, while the eighth and ninth replicas combined are assessed as the second-best replica. The seventh replica predicts positive sufferers every day based on the preceding six days of positive sufferers, whereas the attained findings divulge that perhaps finest anticipations this model was used to create. Eventually, the 7th replica is recommended to forecast day-to-day positive COVID-19 sufferers, especially in the case of districts of Andhra Pradesh which accomplished first wave of such breakout. The 7th ANN model produced high efficient performance in Krishna and Vishakhapatnam of Andhra Pradesh, as demonstrated in the performance network of both districts below. The hybrid semantic neural networks often used forecast the COVID-19 epidemic, the finest prediction findings have not been attained by the identical replica in the case of five major districts of Andhra Pradesh considered. According to Table 3, neural network replicas have non-identical executions and are ranked differently in disparate districts. It could be because; past data of the COVID-19 outburst in Andhra Pradesh are in some way distinctive, although illustrated in Figs. 2 and 3, and dissimilar tendencies outburst accordingly need various forecasting replicas. Therefore, an exploration comparable with the one described in this article is recommended to obtaining the finest neural network replica for a particular district, in the absence of this evaluation, the fourteenth replica is proven to be accurate. Prediction of positive COVID-19 sufferers can have an exact number of not only patients and yet amenities required. Evidently, high reliable positive sufferers are predicted, a clearer picture of the prospective can even be created. Furthermore, evolving semantic neural network replica, which tends to take the preceding 14 days into account, truncates 14-day neural network execution data.

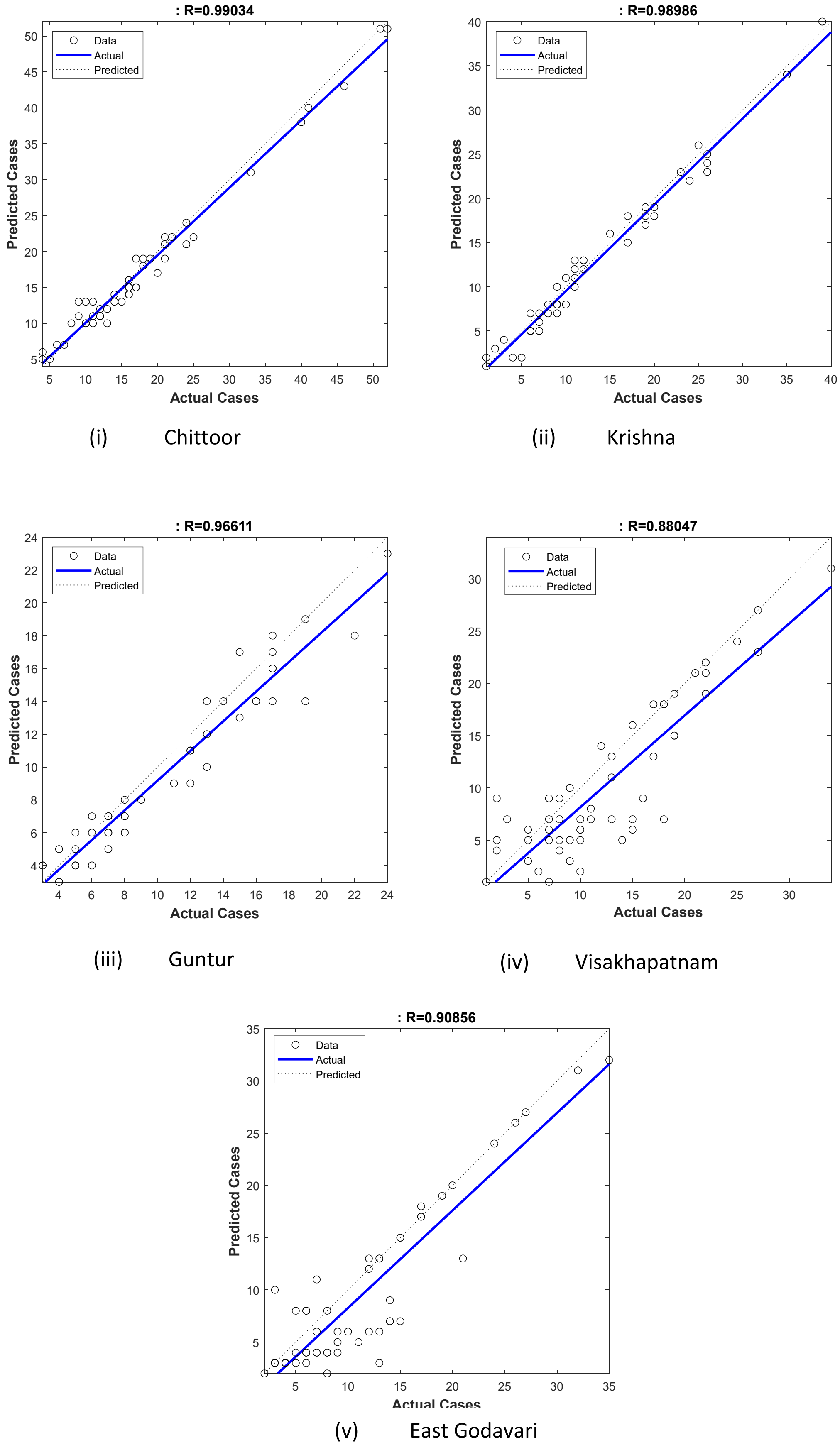
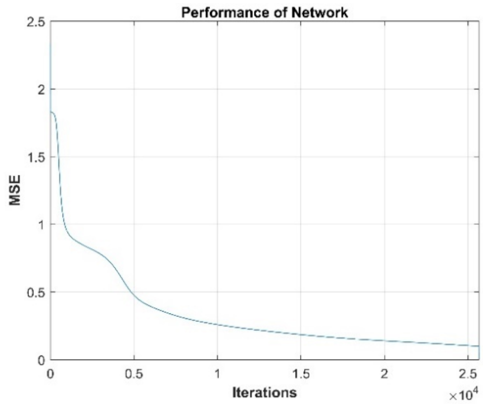
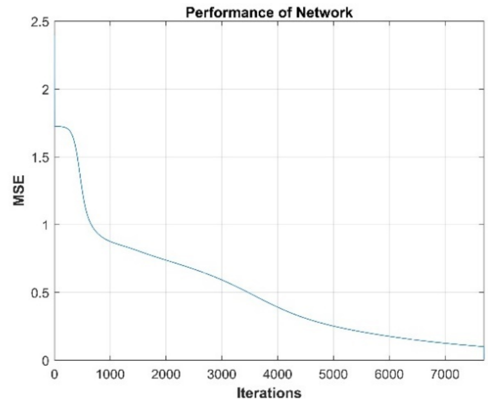


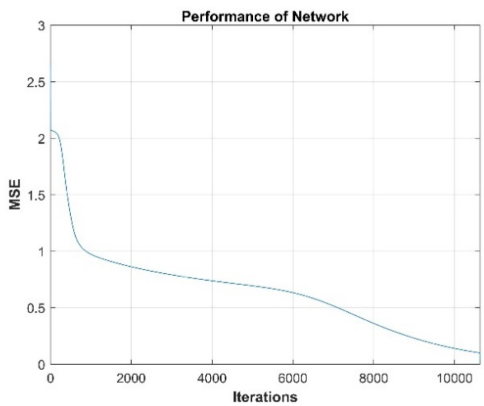
Fig. 6. Regression plot of COVID-19 actual vs. predicted in five major districts of Andhra Pradesh



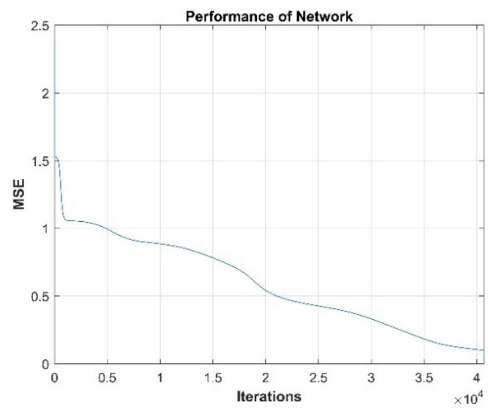
(i) Chittoor



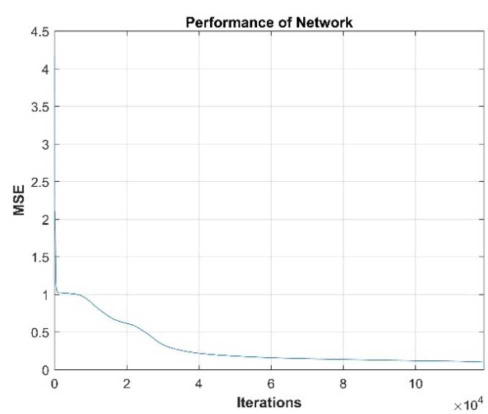
(ii) Krishna



(iii) Guntur



(iv) Visakhapatnam



(v) East Godavari

Fig. 7. Convergence of the best models' efficiency in five major districts

5. Conclusions

In this study, artificial neural network-based prediction models were used to simulate the dissemination of COVID-19. This novel strategy has the potential to alleviate the strain on the medical system whilst also stimulating the economy. In order to evolve the most exact semantic network replicas for anticipating the COVID-19 outburst as a phase of analysis, the fourteen neural network replicas have recommended and analogized in a tender. Its findings designate that the performance of COVID-

19 fertilization duration in neural network replicas provoked high reliable predictions. Recommended semantic neural networks taking fourteen days preceding data is propounded to forecast exact numbers of daily positive cases, especially in five major districts of Andhra Pradesh that have accomplished the initial wave of the COVID-19 outburst. The well-known COVID-19 positive case dataset from Andhra Pradesh, India, was used to evaluate the proposed model. The evaluation experiments also took into account comparisons with the existing approaches. The results demonstrated that in practically all evaluation tests, artificial neural networks outperformed conventional methods such as linear regression, ARIMA, and LSTM. The best prediction models, as well as their RMSE, MAE, MAPE, and R^2 error metrics, have shown in Table 5 for these five districts. Furthermore, the presented forecast models will assist in the prognosis of different diseases, the solving of non-linear complex problems, and the modelling of time series data.

Table 5
Statistical measures for best ANN models

District-ANN model	RMSE	MAE	MAPE	R^2
Chittoor-12th model	2.3418	1.8041	0.1318	0.9669
Krishna-13th model	1.5962	1.2531	0.1834	0.9781
Guntur-14th model	3.4445	2.0478	0.1880	0.9384
Visakhapatnam-7th model	1.9044	1.4358	0.1977	0.9501
East Godavari-6th model	1.5196	1.0888	0.1722	0.9698

Abbreviations

COVID-19: Coronavirus Disease 2019; AI: Artificial Intelligence; ANN: Artificial Neural Networks; MSE: Mean Squared Error; MAPE: Mean Absolute Percentage Error; WHO: World Health Organization.

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