ANN model for one day ahead Covid-19 prediction

Jelena Milojković, Miljana Milić, and Vančo Litovski

Abstract— **One-day-ahead prediction of number of COVID-19 infected patients is presented in this paper. The study is relying on the data available in [1]. A model of artificial neural network (ANN) was developed and used with only the most recent data taken into account. We believe that only a few data from the near past is important for this type of prediction. ANNs have been proven as a very reliable method for the real time prediction systems. In our previous work in prediction electricity consumption [2] and traffic prediction [3], we obtained small prediction error. That encouraged us to conduct the research described in this work. The absence of the trend and the seasonal component in the given time series, made the prediction task more difficult. However, we have obtained good results, which could encourage the application of the model in health management to make better decision in control and prevention of the occurrence of a pandemic.**

***Index Terms*—Covid-19, number of infected, artificial neural network, short-term prediction.**

I. Introduction

Global pandemic, named COVID-19, created his first wave of infection in China in the Wuhan province [4]. It has started in December 19 and continued to the present days. By the World Health Organization (WHO), the virus has affected populations worldwide, and its rapid spread is a universal concern. The high rate of spread as well as the high chance of transmission is still not effective, even with engaging all recommended prevention and implemented control strategies (isolation, detection tests and prophylactic measures). They still have limited effect in preventing or stopping the spread of the virus worldwide [5]. Since its first reporting at the end of December 2019. until 28.04.2022, over 508 million people have been infected, around 500 million people recovered, and 6 227 291 people died due to pandemic [6]. Basic and most important fact of COVID-19 is that it is spreading rapidly by a human-to-human transmission; where about 20% infected subjects are without symptom. The main characteristics of COVID-19 pandemics are high infection rate, incubation period, patients to be contagious during the incubation period, and symptomatic infection [7]. The elderly people and those who have weakened immune systems as well as people with special health conditions such as cancer, hypertension, severe asthma, cardiovascular disease, lung conditions, heart disease, diabetes, neurological conditions, HIV/AIDS infection, pregnancy and high weight are more vulnerable to the serious effects of this pandemic [8]. Based on this we can conclude that a global pandemic like Covid-19 has a high negative impact on the population health, social–cultural activities and global economy [9]. For this reason, it is necessary to develop models to predict the course of events during a pandemic outbreak. In our paper, we used ANN adapted to predict the number of infected on a daily basis. The developed model will help decision-makers, doctors and medical assistants to prepare and understand the magnitude of the risk and take appropriate measures to prevent major leaps. Forecasting tools can also help to assess the extent of risk in a timely manner and make the necessary preparations.

According to the research in the field of Covid-19 prediction by statistical methods, in order to achieve a satisfactory prediction, a basic prediction period of several hundred samples must be used [10, 11]. In the case when we have a set of data of several dozen samples, then time series is presented as a set of trends, random and seasonal components; these models also have a very limited number of parameters. In some cases, even some time series with a striking trend and seasonal component can be predicted with a smaller base period [12]. Actually, the amount of data available in this case is large enough to apply any other prediction method [13, 14, 15], but looking at a diagram curve representing the number of infected patients in one year, we easily recognize that past values of the infected patients are not very helpful when prediction is considered. Accordingly, we propose the problem of prediction of the infected case number in the next day to be performed as a deterministic prediction based on very short time series.

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II. Previous related work

The research in Covid -19 pandemic related with infected case number we describe here is based on our previous results in development and the application of ANN.

In our paper [16] we can see the evaluation of the idea about ANN structures dedicated to short term prediction. First, we will here briefly illustrate the development of two complex ANN structures, which started with a simple one-input-one-output feed-forward ANN.

We first got involved in the ANN based prediction when solving a problem of electronic waste management in Serbia [17]. It came out that there was no systematic way of forecasting the amount of electronic waste to be found in the literature. The main reason for that was the lack of data for a longer period in the past. That inspired us to start with the

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implementation of ANNs that are known as universal approximators. Namely, by using the ANN for approximation of a function represented by a set of equidistantly taken samples one automatically solves one of the biggest problems in approximation: the choice of the approximating function. Furthermore, ANNs are known as very successful interpolators which is frequently defined as a generalization property of ANNs. One had to investigate if ANNs could also extrapolate.

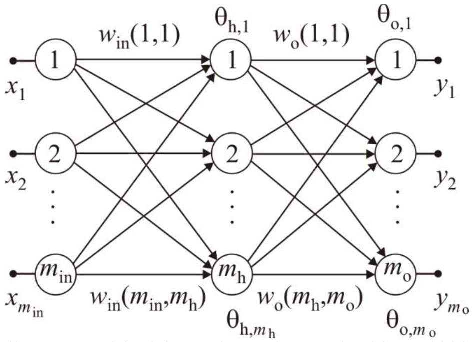

Fig.1. A fully connected feed-forward neural network with one hidden layer of neurons and multiple input and output terminals

This research was conducted in [18]. One fully connected feed-forward neural network is depicted in Fig. 1. To predict the amounts of electronic waste we have implemented a feed-forward ANN, named feed-forward accommodated for prediction - FFAP. The efficiency and good accuracy of the FFAP network inspired us to enter the problem of prediction for consumption of electrical power. There we were confronted with two types of periodicity (daily and weekly) where we have created new structure named Extended FFAP - EFFAP [19].

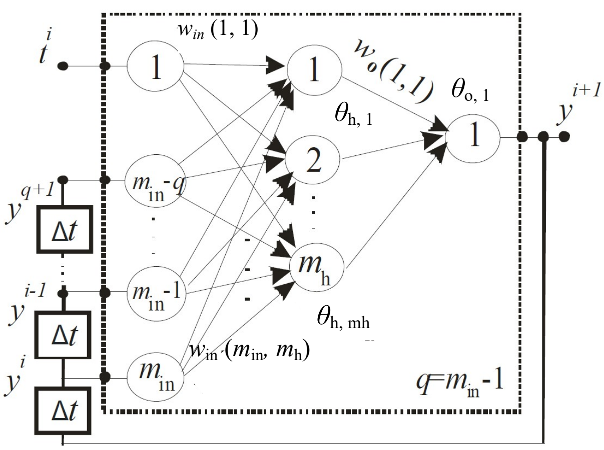

Fig. 2. Time controlled recurrent ANN - TCR

To improve the performance of the ordinary feed-forward ANN, in [20], we examined the capacities of time delayed ANN and evolved to a time controlled recurrent – (TCR) neural network depicted in Fig. 2. The prediction results obtained by the TCR ANN were equally good as those obtained by the FFAP ANN. That was confirmed in its application of prediction in microelectronics [21]. Using similar procedure to FFAP, we have formed a new structure named ETCR (Fig. 3). Two such ANN models we have also applied for prediction of electric power consumption and traffic [2, 3, 22].

III The Method

The basic neural network structure is shown in Fig. 1. It was proven that only one hidden can be sufficient for prediction problem [23] that is the subject of this research. In this figure input layer is denoted with “in”, hidden layer with “h”, and output layer with “o”. The set of weights, $w(k, l)$, connects the input and the hidden layer, where we have: $k=1,2,..., m_{\mathrm{in}}$, $l=1,2,..., m_{\mathrm{h}}$, while for the set that connects the hidden and output layer we have: $k=1,2,...m_{\mathrm{h}}$, $l=1,2,..., m_{\mathrm{o}}$. The threshold levels θ, are here designated with $\theta_{x,r}$, ($r= 1, 2, …, m_{\mathrm{h}}$ or $r= 1, 2, …, m_{\mathrm{o}}$), with x standing for “h” for hidden or “o” for the output layer. The input layer neurons are only delivering the signals, and the hidden layer neurons are activated by a sigmoidal activation (logistic) function. At the end, the output layer neurons have a linear activation function. A variant of the steepest-descent minimization algorithm is applied during the ANN training [24].

To obtain the number of hidden neurons, m_{h}, a procedure based on proceedings given in [25] is applied. In prediction of time series, in that case, a samples dataset is available (acquired in every two hours) which means that only one input signal is enough, and that is the discretized time. According to equation (1) only one output value is predicted at a time, which means that only one output is required, too. Network’s output signals are consumed average power for a period of two hours.

For the implementation of the architecture in Fig. 1, (one input and one output terminal), the following time series would have to be learned: $(t_i, f(t_i))$, $i=1,..., m$.

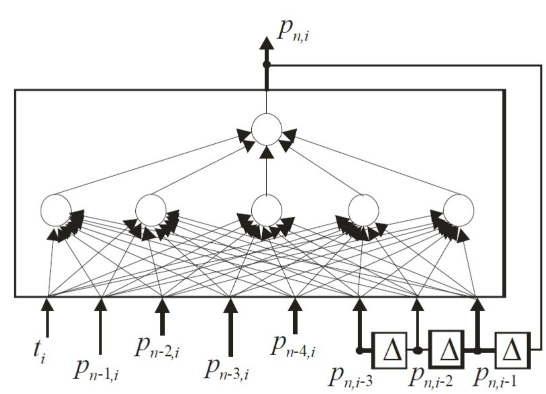

Fig. 3. ETCR. Extended time controlled recurrent ANN

To solve this problem, two new architectures were suggested as the possible solutions. They appeared to be the most convenient for the forecasting problem that is based on the short prediction base period [20]. However, these architectures had to be properly accommodated, due to the availability of data related to previous weeks.

The first network, referred to as a *time controlled recurrent* - TCR, Fig. 2 was derived from the basic time delayed recurrent ANN [26]. The structure has a recurrent architecture

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where time is the input variable, and it controls the predicted value. This structure is then extended, in order to allow that the values for the power consumption at a given time per day, and the values for the same days in three previous weeks, control the output. Consequently, the word *extended* had to be appended. The final architecture is depicted in Fig. 3, and is referred to as the Extended Time Controlled Recurrent (ETCR) architecture. It would be very useful to use the advantages of the ANNs' generalization property and the efficiency of the recurrent structure. This network learns a set in which the output value is controlled by the present time and its own previous instances of the average power consumption for a two hour period in a given day of the week:

$$p_{n,i}=f(t_i, p_{n,i-1}, p_{n,i-2}, p_{n,i-3}, p_{n-1,i}, p_{n-2,i}, p_{n-3,i}), \quad i=3, ..., m. \quad (1)$$

where n stand for the number of the week (in the month or in the year). In that way the values designated with n are from the current week, while the values indexed $n-j$, j=1,2,3, are from the previous weeks. The designation "i" stands for the i-th sample in the selected day. The actual value $p_{n,i}$ is unknown and should be predicted.

The second architecture is referred to as a *feed forward accommodated for prediction* (FFAP) and is shown in Fig. 4. The idea here was to push the neural network to learning the same data window several times simultaneously but shifted in time. It is expected that the previous responses of the function will have larger impact to the $f(t)$ mapping. The architecture has one input terminal - t_i. The approximation y_{i+1} is obtained at the *future* terminal *Output*3. For multiple-step ahead predictions the future terminal can be considered as a vector. The *present* value y_i is represented at the terminal *Output*2. *Output*1 has to learn the *past* value i.e. y_{i-1}. *Output*1 may also be considered as a vector if we need to control the mapping using a *set* of previous values. The functionality of the network could be expressed as

$$\{y_{i+1}, y_i, y_{i-1}, y_{i-2}\} = \mathbf{f}(t_i), \quad i=3, ...,m, \quad (2)$$

where *Output*1={ y_{i-1}, y_{i-2}}. This indicates that one future, one present and two previous responses are to be learned.

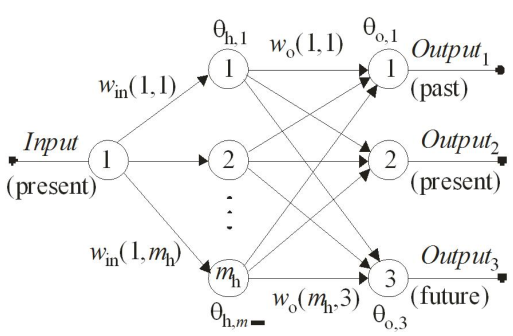

Fig. 4. FFAP. Feed forward ANN structure accommodated for prediction

According to our experience, the FFAP architectures produce more accurate forecasts than the TCR. However, it is a common practice to implement both of them for each forecasting problem and use the results obtained as a reference to each other when choosing the forecast that makes most sense. In this way, we could easily detect and avoid those solutions that represent local minima in the optimization process during the training of the ANN.

In the case of power consumption we have extended the FFAP architecture exactly in the same way as for the TCR architecture. The approximation function could then be written as

$$\{p_{n,i+1}, p_{n,i}, p_{n,i-1}, p_{n,i-2}, p_{n,i-3}\} = f(t_i, p_{n-1,i}, p_{n-2,i}, p_{n-3,i}, p_{n-4,i}), \quad i=4, ...,m. \quad (3)$$

The obtained network can estimate the future (unknown) values $p_{n,i+1}$, using the data for:

- the actual time t_i,
- the actual consumption $p_{n,i}$,
- the past consumption values for the given day in n–th week ($p_{n,i-k}$, k=1,2,3),
- and the past consumption values for the same day and actual time of the previous weeks ($p_{n-j,i}$, j=1,2,3,4).

The new architecture is referred to as an *extended feed forward accommodated for prediction* (EFFAP), and is shown Fig. 5.

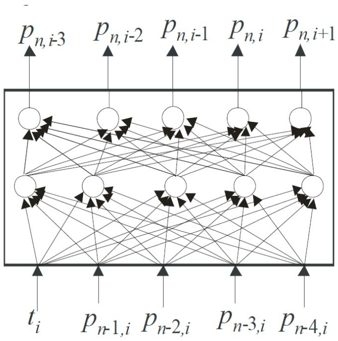

Fig. 5. EFFAP. Extended feed-forward accommodated for prediction ANN

IV. Main Results

Having in mind the nature of the available data we have decided to implement the ETCR structure. A network with 6 hidden neurons was used while 8 previous samples were exploited for prediction.

The procedure could be described with the following steps. Having in mind the random choice of the initial values of the ANN's parameter for training, and the fact that for every such a choice local minima are reached after convergence, we have decided to repeat the prediction for every new day ten times. In that way 10 potential predictions were produced. Then, in order to make a better choice, those with a value above 80% and below 20% of the average were discarded. The final accepted prediction was the average of the rest.

Fig. 6 depicts the prediction results for a 50 day period in the summer of 2021. As can be seen errors not larger than 5% were obtained. This is in accordance with our previous results and, of course, with our expectations.

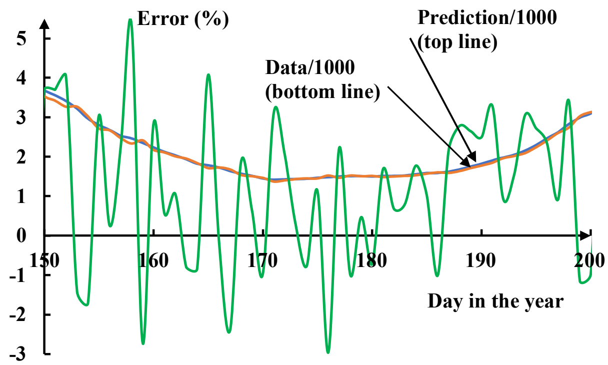

Fig. 6. Prediction results for a 50 day period in the summer of 2021.

V. Conclusion

Based on our 30 years long experience in implementation of ANN in various aspects of technological and social life, we have implemented ANNs for prediction of COVID-19. The results obtained are, in our opinion satisfactory and encouraging for further improvement. That means implementation of other structures as described in the bulk of the paper.

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