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Prediction of treatment cost by artificial neural network of patients with COVID-19 in intensive care unit

Yoğun bakım ünitesindeki COVID-19 hastalarının yapay sinir ağı ile tedavi maliyetinin tahmini

Suna KOÇ[1] (ID), Mehmet DOKUR[2] (ID), Türkan ÖZER[3] (ID), Betül BÖRKÜ UYSAL[4] (ID), Mehmet Sami İSLAMOĞLU[4] (ID), Nilgün AÇIKGÖZ[5] (ID), İlke KÜPELİ[1] (ID), Sena Gül KOÇ[6] (ID), Sema Nur DOKUR[7] (ID), İsmail Tuncer DEGİM[8] (ID)

ABSTRACT

Objective: Artificial neural networks (ANNs) are computer systems that are inspired by the biological neural networks that make up mammalian brains. An ANN is built from a network of linked units or nodes known as artificial neurons, which are roughly modeled after the neurons in the human brain. Each link, like synapses in a human brain, has the ability to send a signal to other neurons. The connections are referred to as edges. Neurons and edges usually have a weight that changes as learning progresses. The weight changes the intensity of the signal at a connection. Artificial neural networks have found applications in a wide range of fields due to their capacity to recreate and simulate nonlinear phenomena. System identification and control, medical diagnostics, data mining, visualization, machine translation, distinguishing highly invasive cancer cell lines from less invasive lines using simply cell shape information, and many more domains are examples

ÖZET

Amaç: Yapay sinir ağları (YSA), memeli beyinlerini oluşturan biyolojik sinir ağlarından esinlenen bilgi işlem sistemleridir. Bir YSA, biyolojik bir beyindeki nöronları kabaca modelleyen, yapay nöronlar adı verilen bağlantılı birimler veya düğümler koleksiyonuna dayanır. Her bağlantı, biyolojik bir beyindeki sinapslar gibi, diğer nöronlara bir sinyal iletebilir. Bağlantılara kenar denir. Nöronlar ve kenarlar tipik olarak öğrenme ilerledikçe ayarlanan bir ağırlığa sahiptir. Ağırlık, bir bağlantıdaki sinyalin gücünü artırır veya azaltır. Doğrusal olmayan süreçleri yeniden üretme ve modelleme yetenekleri nedeniyle yapay sinir ağları, birçok disiplinde uygulama bulmuştur. Uygulama alanları arasında sistem tanımlama ve kontrol, tıbbi teşhis, veri madenciliği, görselleştirme, makine çevirisi, yalnızca hücre şekli bilgilerini kullanarak yüksek düzeyde istilacı kanser hücre dizilerini daha az istilacı hücre dizilerinden ayırt etmek ve diğer birçok alan yer alır. Bu çalışmada, yoğun

[1]Biruni University Medical Faculty, Department of Anesthesiology and Reanimation, İstanbul
[2]Biruni University Medical Faculty, Department of Emergency Medicine, İstanbul
[3]Beysehir State Hospital, Department of Anesthesiology and Reanimation, Konya
[4]Biruni University Medical Faculty, Department of Internal Medicine, İstanbul
[5]Biruni University Medical Faculty, Department of Neurology, İstanbul
[6]Sakarya University Medical Faculty, Sakarya
[7]Biruni University Medical Faculty, İstanbul
[8]Biruni University Faculty of Pharmacy, Department of Pharmaceutical Technology, İstanbul

İletişim / Corresponding Author : Suna KOÇ
Biruni Üni. Hast., Besyol Mah. Eski Londra Asfaltı No:10, Küçükçekmece / İstanbul - Türkiye
E-posta / E-mail : sunakoc@yahoo.com

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of application areas. In this study, ANN analysis was utilized by us to forecast the total cost of therapy or the prognosis of severe COVID-19 the patients in the intensive care unit (ICU).

Methods: The parameters such as ages, and the other biochemical parameters that affect the staying periods (days) of COVID-19 infected patients in ICU were evaluated by using an ANN analysis. For this a computer program, Pythia®, was used to develop ANN models. Real data was used for that selected patients in this study.

Results: The real data obtained from the ICU and gave to the computer as initial parameters. The computer program gave 15 neurons for the first level, one neurons for the second level as the most suitable model for the prediction (SSD = 0.000995). This program predicts a total cost 144.930,94 Turkish Lira (27.300 USD) where the real cost 142.234,06 Turkish Lira (26.792 USD) for the real patient in 2019. This relation was found to be good to predict the possible affected parameters on staying times.

Conclusion: The ANN model developed and released in this research does not necessitate any experimental parameters. Besides, ANN has the ability to deliver helpful and exact prediction or information regarding the expense of COVID-19 patients in ICU.

Key Words: Covid-19, intensive care unit, artificial neural network, treatment, cost

bakım ünitesi (YBÜ)'nde COVID-19 hastasının toplam tedavi maliyetini veya prognozunu tahmin etmek için ANN'den yararlanması amaçlanmıştır.

Yöntem: COVID-19 ile enfekte ağır hastaların YBÜ'de kalış sürelerini (gün) etkileyen yaş gibi parametreler ve diğer biyokimyasal parametreler YSA analizi kullanılarak değerlendirilmiştir. Bu çalışmada, bir bilgisayar programı olan Pythia® YSA modellerini geliştirmek için seçilen hastalara ait veriler kullandık.

Bulgular: YBÜ'den elde edilen ve başlangıç parametreleri olarak bilgisayara verilen gerçek veriler elde edilmiştir. Bilgisayar programı tahmin için en uygun model olarak birinci seviye için 15 nöron, ikinci seviye için bir nöron vermiştir (SSD = 0,000995). Bu program, gerçek hasta için 2019 yılındaki gerçek maliyeti 142.234,06 TL iken toplam maliyeti 144.930,94 TL olarak tahmin edilmiştir. Bu ilişkinin, kalış süreleri üzerindeki olası etkilenen parametreleri tahmin etmede iyi olduğu görülmüştür.

Sonuç: Bu çalışmada, geliştirilen ve yayınlanan YSA modeli herhangi bir deneysel parametre gerektirmemektedir. Ayrıca YSA, YBÜ'deki COVID-19 hastalarının masraflarıyla ilgili yararlı ve kesin tahmin veya bilgi sağlama yeteneğine sahiptir.

Anahtar Kelimeler: Covid-19, yoğun bakım ünitesi, yapay sinir ağı, tedavi, maliyet

INTRODUCTION

ANN models and many other models developed for prediction using artificial intelligence are becoming widespread and increasingly used in medical and pharmaceutical research to predict the nonlinear correlation between causal factors and response variables (1, 2). ANN is a computer algorithm inspired by biological systems and their working methodology. It is designed to learn from data in a way similar to the brain's learning processes. The vast majority of ANNs are multidimensional, nonlinear information processing systems (3, 4). ANNs are data-analysis machines made up of hundreds of independent artificial neurons. Artificial neurons are connected together by coefficients (weights), which create the neural structure, and are organized in layers, which include the input layer, the output layer, and hidden layers in between. Neural networks learn by finding patterns and discovering correlations in data, and they are taught with appropriate learning instances through experience (5).

The purpose of this study is to calculate the costs of severe patients hospitalized in the isolated intensive care unit with the diagnosis of COVID-19, using artificial neural networks in the most realistic way and to make forward-looking cost-analytical estimates based on this.

Having input, hidden and output processes similar to those in biological neural systems, and because of their ability to reproduce and model nonlinear processes, ANN have found applications in many scientific fields such as to diagnose several types of cancers and to distinguish highly invasive cancer cell lines from less invasive lines using only cell shape information. ANN is also used successfully in electronic aviation fields system identification and control such as vehicle control, trajectory prediction, process control, natural resource management, quantum chemistry, general game playing, pattern recognition such as radar systems, face identification, signal classification, 3D reconstruction, object recognition and more, sensor data analysis, sequence recognition such as gesture, speech, handwritten and printed text recognition, medical diagnosis, finance, data mining, visualization, machine translation, social network filtering and e-mail spam filtering. Besides, ANNs have been used to accelerate reliability analysis of infrastructures subject to natural disasters and to predict foundation settlements (6).

In this study, we preferred Pythia® as a suitable ANN model to estimate the total cost for the treatment of COVID-19 patients in the University Hospital Intensive Care Unit (ICU).

MATERIAL and METHOD

Data collection and processing

Initial data was obtained from hospital data sources by retrospective searches. After data collection, all values were entered into the Excel program. All parameters were accepted as inputs and total cost of the treatments for each patient were entered as output. The computer program Pythia® accepts copy/paste from Excel columns. After copying inputs and the output, the future function of the Pythia program called "Evolutionary optimisation" was chosen and program ran. Finally, the program gave the best neural network model indicating the number of neurons at layer by considering the least sum of squares of the deviations from the real data. The program was trained to use a given neural model for the real data. After the training program was ready for predictions. These predicted values were finally compared with the real data.

Development of ANN

The input layer neurons obtain data and the output neurons produce the ANN's response. The parameters affecting the duration of stay (days) of COVID-19 infected patients in ICU were evaluated by using an ANN analysis. ANN models were developed using selected input parameters (age, co-morbidities, length of stay in ICU, cost of treatment per patient and the other biochemical parameters) determined after accepting them in ICU. A computer program, Pythia®, was used to develop ANN models (The Neural Network Designer version 1.0-Runtime Software LLC; Carson City, NV) (7). The software provided the best configurations and number of neurons at each level for predicting the total cost of the treatment of the COVID-19 patients. The superior fit was 16 neurons. A total of 19 inputs were used and the average SSD (sum of squared deviations) was calculated as 0.000995 after training. The best network model was developed using the optimizer and the ANN that achieved the lowest square deviations.

In this study, the most suitable ANN models were computed and developed for prediction of total cost of the treatment of 201 COVID-19 patients treated in ICU. The computer program run-Pythia®-uses back propagation networks to achieve the best model. The parameters of network (weights) were initially set to random values. During the training phase, the actual outputs compared with the desired (real) outputs and the error value propagated back toward the input of the network. A special feature of the

program called evolutionary optimizer automatically generates suitable networks and it is able to find the best one for given set of data. The program achieves the best network structure based upon lowest square deviations.

The study protocol was permitted by Biruni University Faculty of Medicine Ethics Committee (Date: 29.07.2020 and Number: 2020/42-05). The study was completed according to the mandates of the Helsinki.

RESULTS

The real data was obtained from the hospital unit and entered to the computer as initial parameters. The computer program gave 15 neurons where 19 inputs were used for the first level and one neuron for the second level as the most suitable model for the prediction. The average SSD was calculated as 0.000995 after training. The predicted treatment cost of patients is given in Figure 1.

The network output was plotted against two input descriptors to generate a functional dependency surface but this returned highly complex responses between the input variables yet there was no clear and easy-to-understand correlation. However, the real data and the predicted values were in the scope of predictability. As an example, program predicted a total cost of 144.930,94 Turkish Lira (27.300 USD) where the real cost was 142.234,06 Turkish Lira (26.792 USD) for the patients in 2019 (Figure 2).

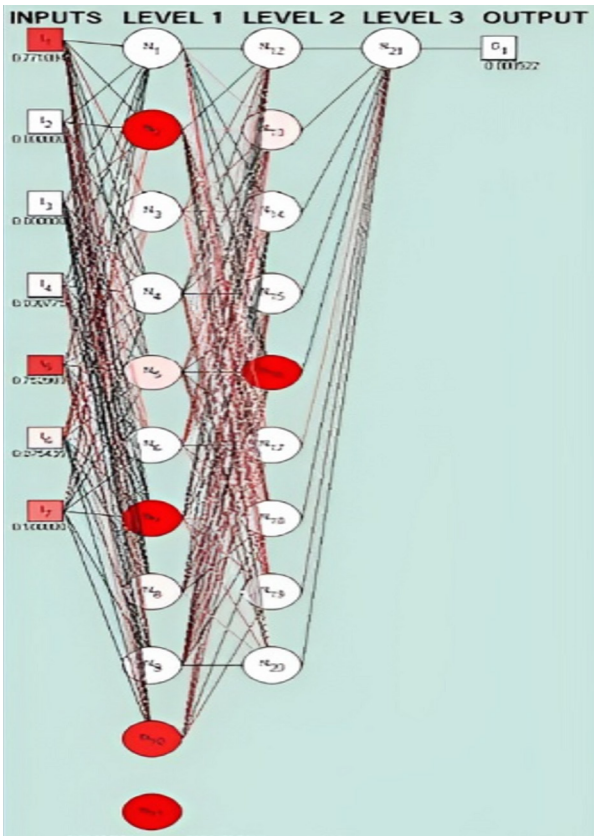

Figure 1. Prediction of total cost for the treatment (graphical scatter plot)

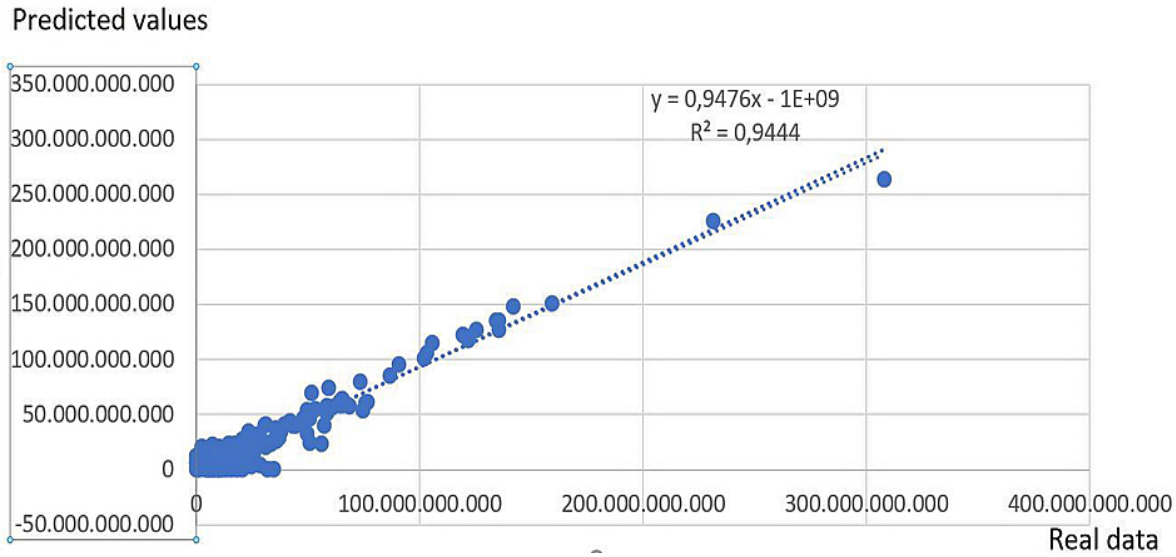

Figure 2. Prediction of total cost for the treatment (in Turkish Lira, based on 2019) (linear scatter plot)

DISCUSSION and CONCLUSION

The used computer program Pythia uses back propagation networks to achieve the best model (1, 3). The parameters of network (weights) were initially set to random values. During the training phase, the actual outputs were compared with the desired (real) outputs and the error value propagated back toward the input of the network. A special feature of the program called evolutionary optimizer automatically generates suitable networks and it is able to find the best one for given set of data. The program achieves the best network structure based upon lowest square deviations (8).

The ANN calculations have two phases. Initial phase referred as "training phase" and the final phase called "reproduction phase". When training phase is completed, the network and each neuron get the exact value for fermi function and during the reproduction phase parameters are set and remain unchanged. In back propagation networks, each neuron has one output and as many inputs as neurons in the previous level. Each network input is connected to every neuron in the first level. Each neuron output is connected to every neuron in the next level. The network's output is the output of the last level neurons. The network is processed from left to right in the given model (9). The ANN findings showed that the computer program made predictions successfully and the correlation between parameters were found to be complex (10). These complex correlations were defined successfully by ANN and estimations were conducted rapidly after system training. The interpretation of the effects of each descriptor parameter is difficult since the model is multivariate and nonlinear. However, some insight into the degree of nonlinear behaviour of the descriptors has been assessed with a functional dependence to understand the relationships. The value of the input variables varied through a range, whereas some others were almost constant (11). It is also possible to predict a total cost for a hypothetical patient for whom the input parameters are known. In a study in

which Kulkarni A, et al. (12) evaluated the prolonged hospitalization periods of patients hospitalized in the coronary intensive care unit after angiography, it was shown that the longer the poor prognostic indicators increased, the longer the hospitalization periods get.

In recent years, parametric prediction studies have increased in clinical sciences using artificial neural networks to determine the accuracy of diagnosis and the prognosis of critically ill patients (13-18). Prediction studies using artificial neural networks can reflect cost-effectiveness analyzes in clinical sciences. It is especially important to be able to predict the actual cost of the medical treatment prior to the decision for especially physicians, hospital management and also for medical authorities. Beside that, the medical decision makers and doctors should also be aware of the actual costs before application of the therapy. These personnel should also be aware of what biomedical parameters can actually make the condition of the aforementioned patient worse. These biochemical markers or parameters are also predictive for the patient's medical conditions subsequently. This study may be the first study which searches for a relationship between biochemistry and the patient's conditions and finally predicts the total cost of the future therapy. This beneficial prediction may help the medical personnel and indicates what biochemical factors are important for the rapid recovery of the Covid-19 patients and also may give a perspective on how to reduce total costs.

In conclusion, all results of our study showed that developed and trained ANN model is useful to predict the total treatment cost of the patients with COVID-19 and the correlations between parameters were found to be complex. Despite the presence of these complex relationships in parameters, it is more difficult to make predictions using other traditional methods; our estimations were found to be rapid and feasible after easy system training and parameter input. Besides, this illustration is good to predict the duration of stay of COVID-19 patients in ICUs. This is crucial since predicting the days of stay may help health professionals to reduce the cost of treatments. It may even be possible to order some necessary consumables and drugs prior to treatment. The ideology and the network or calculation method can be easily adapted to the other subjects.

ETHICS COMITTEE APPROVAL

* The study was approved by the Biruni University Faculty of Medicine Ethics Committee (Date: 29.07.2020 and Number: 2020/42-05).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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