<u>*Araştırma Makalesi*</u>   <u>*Research Article*</u>

ANN Supported Decision System Performance in Diagnosing Parkinson's Disease*

Uğur Fidan [1], Neşe Özkan Yılmaz [2**]

[1]Biomedical Engineering, Faculty of Engineering, Afyon Kocatepe University, Afyonkarahisar, Turkey (ORCID: 0000-0003-0356-017X)
[2*]Biomedical Engineering, Faculty of Engineering, Afyon Kocatepe University, Afyonkarahisar, Turkey (ORCID: 0000-0003-4411-4838)

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Abstract

Parkinson's disease (PD) is a neurodegenerative disease that results in the loss of function of dopamine- producing brain cells. Primer designation of PD; is seen as tremor in the upper and lower limbs in 70% of the patients, and as in slowing and stiffness in the movement in 30% of them. Archimedes spiral technique is a clinical test method developed for examining PD motor disorders. The reliability and validity of the spiral test drawing technique was statistically proven by comparing it with the Unified Predictive Rating Scale (UPDRS). In this study, it was aimed to construct a static spiral test and a dynamic spiral test drawings, to extract the characteristics using the signal processing techniques and to identify the Parkinson's disease using the artificial neural network model. In the classification of the disease, only SST and ANN using only DST and f score ratio in the classification were found to be 0.95 and 0.92, respectively. When SST and DST methods were evaluated together, ANN classification success was found to be 0.99. For this reason, it was found that SST and DST methods were more successful in the classification of the disease than the classification using SST and DST alone. Using the combination of SST and DST data as a result of the study, PD was classified with artificial intelligence techniques with an accuracy of 98.6% and a score of 0.99 f.

Keywords: *Biomedical Signal Analysis, Parkinson's Disease, Artificial Neural Network (ANN), Spiral Analysis.*

Parkinson Hastalığının Teşhisinde YSA Destekli Karar Sistemi Başarımı

Öz

Parkinson hastalığı (PD), dopamin üreten beyin hücrelerinin işlev kaybıyla sonuçlanan nörodejeneratif bir hastalıktır. PD'nin primer tanımı; hastaların% 70'inde üst ve alt ekstremitelerde titreme,% 30'unda harekette yavaşlama ve sertlik gibi görülür. Arşimet spiral tekniği, PD motor bozukluklarını incelemek için geliştirilmiş bir klinik test yöntemidir. Spiral test çizim tekniğinin güvenilirliği ve geçerliliği, Birleşik Tahmin Derecelendirme Ölçeği (UPDRS) ile karşılaştırılarak istatistiksel olarak kanıtlanmıştır. Bu çalışmada, statik bir spiral test ve dinamik bir spiral test çizimlerinin yapılması, sinyal işleme teknikleri kullanılarak karakteristiklerin çıkarılması ve yapay sinir ağı modeli kullanılarak Parkinson hastalığının belirlenmesi amaçlanmıştır. Hastalığın sınıflandırılmasında, sadece sınıflandırmada sadece DST ve f skor oranı kullanan SST ve YSA sırasıyla 0.95 ve 0.92 olarak bulundu. SST ve DST yöntemleri birlikte değerlendirildiğinde YSA sınıflandırma başarısı 0,99 bulunmuştur. Bu nedenle, hastalığın sınıflandırılmasında SST ve DST yöntemlerinin sadece SST ve DST kullanan sınıflandırmalardan daha başarılı olduğu bulunmuştur. Çalışma sonucunda SST ve DST verilerinin kombinasyonu kullanılarak PD,% 98.6 doğruluk ve 0.99 f skoru ile yapay zeka teknikleri ile sınıflandırılmıştır.

Anahtar Kelimeler: *Biyomedikal Sinyal İşleme, Parkinson Hastalığı, Yapay Sinir Ağları (YSA), Spiral Analiz.*

1. Introduction

Parkinson's disease (PD) is a neurodegenerative disease that results in the loss of function of dopamine-producing brain cells. Typical symptoms are tremor, stiffness, slowing of body movements (bradykinesia), unstable posture, and walking difficulty [1, 2]. Although the cause of the disease is not fully known, genetic and environmental factors have been reported in the literature [3]. Despite advances in imaging and genetics, the diagnosis of PD remains dependent on clinical evaluation [4]. Primer designation of PD is seen as tremor in the upper and lower limbs in 70% of the patients, and it is in the form of slowing and stiffness in the movements 30% of them [5]. When studies in the literature were reviewed to help diagnose PD, Pullman et al. used a spiral analysis method to diagnose tremor in the Parkinson's disease with a digital tablet. Archimedes spiral technique is a clinical neurological test used to measure motion disturbances caused by motor disorders in Parkinson's patients. It is preferred from the point of view that the applied spiral technique is fast, reliable, inexpensive and noninvasive. Kinematic measurements are obtain by plotting the arched spiral with 15 PD, 15 normal, 15 muscle tone disorders and 15 basic tremors in the study. The frequency, power, X, Y coordinates and pressure data are compared and the result is that archived spirals are reliable in the diagnosis of Parkinson's disease [6]. Gemmert et al. worked with 13 PD and 13 control groups in their study. The participants wanted to write "llll" and "lili" expressions with handwriting. Using five different font sizes, the writers compared the vertical axial acceleration values of these expressions as desired [7]. Pullman et al. tested spiral test drawings in Parkinson's disease. The spiral test drawings and the UPDRS (Unified Parkinson's Disease Rating Scale) test scale were compared. Statistical analyses have shown that the resultant spiral test drawings are as successful as the UPDRS scale in detecting PD [8]. Sakar et al. analyzed the voice of Parkinson's patients with multiple voice recording types. It was based on the difference between the people diagnosed with PD and the voices of healthy people and the difference of sound vibration. Twenty healthy volunteers and 20 PD people aged 43-77 years were used. In these persons, the voice data were recorded by saying "a" and "o" three times. On these data, the k-NN (k-Nearest Neighbor) algorithm and SVM (Support Vector Machines) method are applied and the success cases were compared. The SVM method is more successful than other classification methods in PD detection through voice data [9]. Isenkul et al. performed the Static Spiral Test (SST) and the Dynamic Spiral Test (DST) with the program they had on the tablet in Parkinson's patients. People with Parkinson's disease were asked to use SST and DST drawings using pencils and tablets, using the difficulty of handwriting. In the study, 15 healthy persons and 25 persons with Parkinson's disease were used. The distances between the two points from the SST and DST plots of the subjects were compared and compared, and a tablet-based remote monitoring system was designed to measure the cortical and motor performances of the subjects [10]. In the studies performed, the success of the spiral analysis test in detecting early PD was demonstrated statistically [11, 12].

Studies in the literature focus on the method of SST or DST for the classification of Parkinson's disease and which method is more decisive. In this study, it is predicted that performing both methods together will increase the success of classification of the disease. In this study, it is aimed to increase the classification success of Parkinson's disease by using Static Spiral Test and Dynamic Spiral Test Drawings and to perform self-extraction using signal processing techniques and to increase the classification success of Parkinson's disease by using artificial neural network model.

2. Material and Metod

The data set under the heading "Parkinson Disease Spiral Drawings Using Digitized Graphics Tablet Data Set" of the Machine Learning Repository (UCI) database was used in the current study. Using the Wacom Cintiq 12WX tablet, the data were obtained as a result of static and dynamic spiral drawings of 15 healthy persons and 58 patients with the disease. In the Static Spiral Test, individuals are expected to draw on the spiral displayed on the screen. In the Dynamic Spiral Test, the spiral drawing given to the screen is displayed and closed at certain time intervals. During the Dynamic Spiral test, individuals are expected to complete using the drawing memory. Data are collected during the test; and X-, Y-, and Z-positions of the floor, the pressure and grip angle, and the time and the type of test information, respectively [13]. The X, Y coordinate, time and test type data in the collected signals are processed and interpreted using the algorithm shown in the flow diagram in Figure 1. First, the distances from the center to the X, Y coordinates were determined using the Euclidean equation in Equation 1.

$$D = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2} \qquad (1)$$

Fast Fourier Transform (FFT) was applied to the distance information to the center. The sampling frequency required for FFT conversion was subtracted from the time information in the aggregated data. The first 20 of the frequency components obtained as a result of the FFT transform were determined as the attributes of the data. Attribute parameters were applied to the Artificial Neural Network (ANN) to classify the data as Normal or Parkinson.
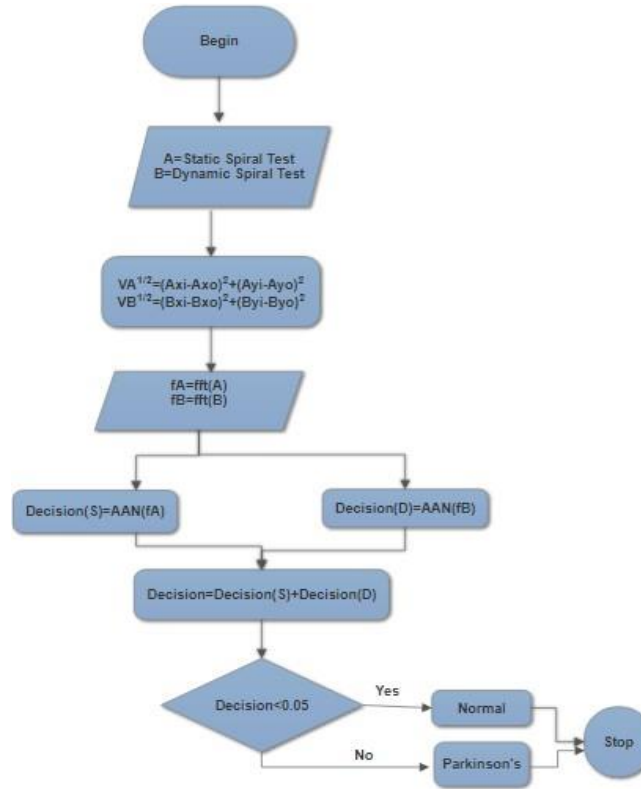
Figure 1. Flow diagram

2.1. Attribute Inference and Fast Fourier Transform

Attribute extraction is the process of determining the attributes that define all the data and obtaining the feature vector. Attribute selection reduces the input vector of the classification process with an operation that is done depending on the request. The choice of an appropriate feature vector is at the forefront of the factors that influence the AAN success rate. The Fourier transform method, which is used to define an input sequence in the frequency domain instead of the time domain, is an efficient feature extraction technique. FFT was developed by Cooley and Tukey in 1965 to alleviate the burden of N^2 multiplication in the computation of the Discrete Fourier Transform and a computational burden of the N-1 addition. Given the angular frequency (w), values of the x(t) sign defined in the time domain of the FFT equation (Eq.2) [14].

$$F(w) = \int_{-\infty}^{+\infty} x(t)e^{-i\omega t}dt \qquad (2)$$

2.2. Multilayer Artificial Neural Network

Multilayer feedforward artificial neural network (MLFANN) consists of three basic layers: input layer, hidden layer and output layer. The training of artificial neural networks works according to the teacher learning strategy. Back propagation learning algorithm is mainly used in this algorithm. In order to realize the artificial neural network, two types of samples are collected: training set and test set. How many neurons are used in the network determines the number of input units and the number of hidden layers. The learning coefficient determines parameters such as momentum coefficient and addition and activation functions. The collected test data is shown to the network and the net output is calculated in response to the information presented to the input layer with the hidden layer. Training is continued by updating the weights of the layers until reaching the target output [15].

2.3. Levenberg-Marquardt Algorithm

The Levenberg-Marquardt (LM) algorithm is a method of least squares calculation. This algorithm combines the best features of Gauss-Newton and Steepest-Descent algorithms and removes the constraints of these two methods altogether. In summary, the working principle of this algorithm is as follows. The start value is calculated by calculating the weights of the assigned weights and the squares of the errors. Each error calculated is the difference between the target output and the actual output value. The values of the weight vector are determined by applying the steps of the Levenberg-Marquardt method in Table 1 by obtaining all of the error terms for the entire data set [16–18].

Table 1. Levenberg-Marquardt method application steps

Step 1	The performance function E (W, n) is calculated,
Step 2	Starting with a small μ value ($\mu = 0.01$),
Step 3	By calculating ΔW, the next value of the performance function is calculated,
Step 4	If the next value of the performance function is greater than the current value, μ is increased by 10 times,
Step 5	If the next value of the performance function is less than the current value, μ is reduced by 10 times,
Step 6	The weights are updated and then it is necessary to step 3.

3. Conclusions and Recommendations

The AAN-supported decision system software for PD diagnosis was prepared in 64 bit Matlab R2016a on a laptop computer with 2.4GHz i7-4700HQ processor. Figure 2 and Figure 3 show the results of the drawing by the X, Y coordinates of the data obtained from the SST and the DST, the distance information to the center and the frequency spectrum results. When the graphs in Figure 2 are examined, it is seen that there is no significant difference found between SST or DST results for healthy individuals.
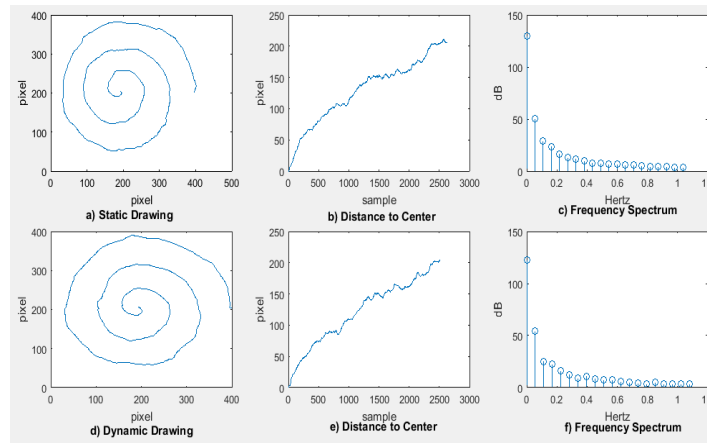

Figure 2. Healthy Individual SST and DST Data

When the SST and DST graphs for PD in Figure 3 are examined, it is observed that the drawing, center distance, and frequency spectra of the signals obtained for the two different test methods vary.

When Figure 2a and Figure 3a are compared, there is no significant difference detected in the shape, but there is enough change to describe the PD between the center distance information in Figure 2b and Figure 3b. This change is also found in Figure 2c and Figure
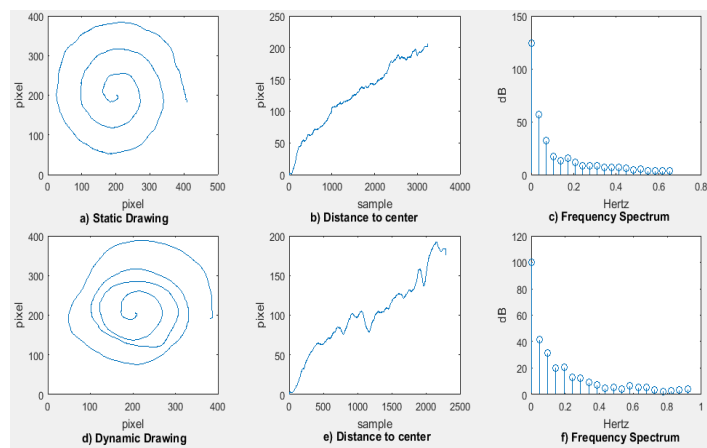

3c.

Figure 3. PD SST and DST Data

The DST results developed by Isenkul and colleagues as alternatives to traditional SST were more effective in diagnosing PD the ones seen in the variation in the frequency spectrum in Figure 3c and Figure 3f. Since the frequency spectrum results reflected the whole of the SST and DST results, it was designated as the feature vector and it constituted the input data of AAN.

Figure 4 shows the AAN model. The feature vectors obtained from the healthy 58 PD were trained using the Levenberg-Marquardt learning algorithm for SST and DST using the nftool function of Matlab R2016a.

The AAN functions obtained from the training of the network are used in the PD decision system depending on the algorithm in Figure 4. The performance of the decision system was tested using the binary classification test (Figure 5).

Table 2 shows the f scores of the conventional spiral test, the dynamic spiral test proposed by Isenkul and the decision system obtained through the joint use of both test methods. f Score value is defined as a measure of accuracy of a test used in the statistical analysis of binary classification [19]. When the results in Table 2 are evaluated, it is seen that only the SST or DST decisions are related with the diagnosis of PD, whereas the decision according to the results obtained from both methods is seen to be the determinant of the diagnosis of PD.
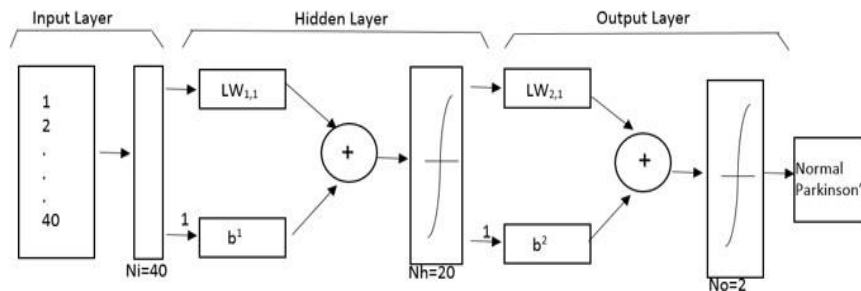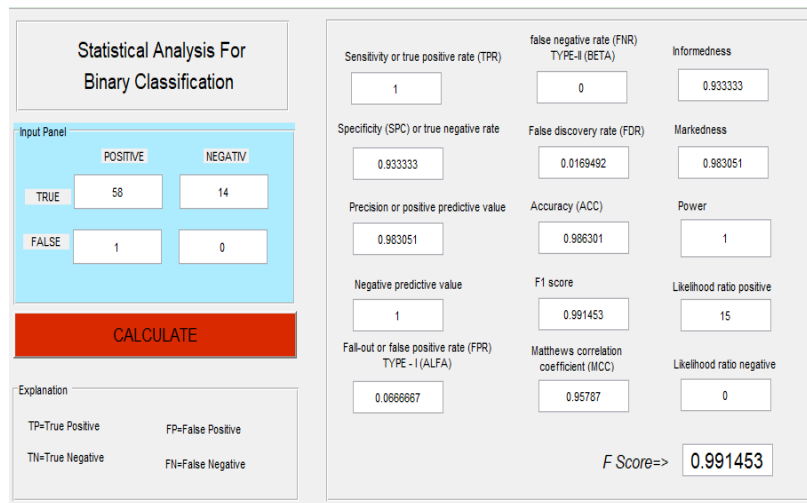

Figure 4. Realized ANN Model

Figure 5. Binary Classification Test

4. Conclusion

Although the cause of PD, whose typical symptoms are tremor, stiffness, bradykinesia, and so on, is not fully known, genetic and environmental factors are influential on the disease. While 70% of the patients show tremor in their extremities, 30% of them show slowing and stiffness in their movements. Despite advances in imaging and genetics, the diagnosis of PD depends on clinical evaluation.

Different models and techniques have been developed in the literature for the diagnosis and diagnosis of Parkinson's disease. When the studies in the literature were examined, gait rhythms of ALS, Parkinson's and Huntington's patients were compared with statistical methods and walking performance was analyzed [20]. In another study, 90% of Parkinson's patients were classified by SVM (Support Vector Machine) method. The success of the classification made by SVM method is 92.75% [21]. In a different study on voice changes in Parkinson's patients, SVM, k-NN (k-Nearest Neighbors) and Matthew's Correlation Coefficient were used. In this classification problem, the highest accuracy of 96.4% and Matthew's Correlation Coefficient of 0.77 is obtained using support

vector machines with third-degree polynomial [22]. Sakar et al. conducted a sound analysis of patients with Parkinson's. Wavelet transform, a signal processing technique, was applied to the received audio data and the mel frequency was examined [23]. Lee et al. In their study, gait performance analysis of Parkinson's patients was performed. Sensitivity specificity values were compared with normal subjects after feature extraction [24]. Bilgin has demonstrated the success of classification in other neurodegenerative disease groups, including Parkinson's disease, using gait analysis using the naive bayes classification method [25]. Zeng et al. found the accuracy of the gait performance analysis of Parkinson's patients to be 96.3% using the five-fold cross-validation method [26]. Baratin et al. evaluated the gait analysis of other neurodegenerative disease groups including Parkinson's disease. The classification success rate was 85% [27]. Archimedes spiral technique is a clinical test method developed for examining PD motor disorders. The reliability and validity of the spiral test drawing technique was statistically proven by comparing it with the Unified Predictive Rating Scale (UPDRS). Isenkul et al. By developing this technique, they have brought the DST technique to the literature. What they have done enabled them to monitor their patients with parkinson's disease with telemedicine. However, there was no expert decision system in their system. In the present study, different from the studies in the literature, SST and DST were used to classify individuals as healthy or PD with the AAN techniques. It was determined that classification using only SST or only DST was more successful in classifying the disease than by evaluating both methods When the studies in the literature are examined, it is seen that hand writing or spiral drawing methods help the physicians in the diagnosis of disease. In the study conducted using both SST and DST, the two drawing techniques were compared by looking at the distances between the points in the drawings and their DST and SST methods combined with the use of the f score value obtained in the study is more successful than the use of separate methods have been interpreted that the success rate. In the study using SVM and k-NN classification, the success rate was found to be less than that of ANN [9].

As a result, using SST and DST data together, PD was classified with artificial intelligence techniques with 98.6% accuracy and 0.99 f score. However, a greater number of learning and test data are needed to make the resulting conclusion a general judgment. This work should be continued by obtaining these data and determining the effect on system performance.

Table 2. F Scores for AAN Models

SST ANN		DST ANN		SST & DST ANN	
Healthy	Parkinson's	Healthy	Parkinson's	Healthy	Parkinson's
15	53	14	51	14	58
0	5	1	7	1	0
F score=0.954955		F score=0.927273		F score=0.991453	

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