ADBA
Computers and Electronics in Medicine
Cutting-Edge Scientific Solutions

e-ISSN: 3023-8609
RESEARCH ARTICLE
Vol.1 / No.1 / 2024 / pp.18-23
https://doi.org/10.69882/adba.cem.2024073

ANN Algorithms for Parkinson's, ALS, Huntington, and Healthy Walking Detection

Fatma Betül Derdiyok *,1 **and Kasım Serbest** α,2

*Sakarya University of Applied Sciences, Department of Biomedical Engineering, 54050, Sakarya, Turkiye, αSakarya University of Applied Sciences, Department of Mechatronics Engineering, 54050, Sakarya, Turkiye.

ABSTRACT In this study, the utilization of artificial neural networks (ANN) algorithms, in the diagnosis of neurodegenerative diseases were examined. Data obtained from the measurement of walking parameters were evaluated for disease diagnosis using the ANN model among individuals with ALS, Parkinson's, Huntington's, and healthy individuals. Comparative analyses conducted using Levenberg-Marquardt, Bayesian Regularization, and Scaled Conjugate Gradient algorithms demonstrate that the Levenberg-Marquardt algorithm provides the most effective diagnosis with a success rate of 99%. This study highlights the potential of artificial neural networks in the early diagnosis of neurodegenerative diseases and lays a foundation for future research. In conclusion, artificial neural networks may play a significant role in the diagnosis of neurodegenerative diseases, but further research and method development in this area are warranted.

KEYWORDS
Machine learning
Neurodegenerative diseases
Disease diagnosis
Parkinson's
ALS
Huntington

INTRODUCTION

The control mechanism responsible for the movement of muscles and joints is provided by our nervous system (Bart 2018). Among the fundamental structures that make up our brain are nerve cells, or neurons, and the points where these neurons connect with other neurons, called synapses. All the processes in our nervous system and our memory are associated with electrical currents in neurons. The exchange of information between neurons occurs through these electrical currents. Signals from our brain or other parts of the central nervous system are transmitted to the muscles and joints responsible for movement via motor neurons; the point where muscle and nerve meet is called the motor unit (Yuldashev 2022). Damage or wear and tear that may occur in neurons and motor units can lead to disruptions in nerve transmission, causing problems in our movement system and senses. Additionally, improper functioning of the connections between nerve cells in the brain, known as synapses, can also cause disruptions in many systems, especially the movement system. Such disorders are generally referred to as neurological diseases (Aslan *et al.* 2021).

Amyotrophic lateral sclerosis (ALS) is the most common among acquired motor neuron diseases. Although not certain in our country, it is estimated that the prevalence is 3-8/100,000 and the annual incidence is in the range of 1-2/100,000 globally. The symptoms of the disease vary individually, but commonly include muscle atrophy and weakness, communication difficulties due to speech, pain, difficulty swallowing (dysphagia), deep vein thrombosis, respiratory failure, fatigue, sleep problems, anxiety, and depression (Kaya and Özcan 2017). In the advanced stages of ALS, patients lose their motor functions. As muscle weakness progresses, there are losses in basic physical abilities such as speech, swallowing, hand use, and walking, making communication with patients increasingly difficult (Turner and Benatar 2015).

Huntington's disease is a genetic disorder characterized by progressive neurodegenerative processes. It is more common, especially in Northern European countries, with a prevalence reported to be approximately 10-13 cases per 100,000 people (McColgan and Tabrizi 2018). This disease is accompanied by uncontrolled movements, progressively worsening cognitive functions, and psychiatric disorders. Motor symptoms typically appear at the onset of the disease; clumsiness, difficulty in eye movements, uncontrolled movements, slowing of movements, and speech disorders become apparent in the early stages (Gültekin and Ekinci 2017). In the later stages of the disease, symptoms such as uncontrolled movements, slowing of movements, spasticity, and rigidity develop in addition to motor signs. At the cognitive level, slow progressive cognitive impairment, forgetfulness, attention deficits, and in later stages, speech difficulties and dementia may be observed. The diagnosis of Huntington's disease is based on clinical examination, the pres-

Manuscript received: 25 April 2024,
Revised: 9 May 2024,
Accepted: 15 May 2024.

[1]22500305004@subu.edu.tr
[2]kserbest@subu.edu.tr (**Corresponding author**)

ence of similar histories in the family, and genetic analyses (Bates *et al.* 2015).

Parkinson's disease is the second most common neurodegenerative disorder after Alzheimer's disease, and its frequency increases with age (Marsden 1994). Although primarily considered a movement disorder, psychotic and cognitive impairments are also frequently associated with this disease. Parkinson's disease is understood to be characterized by approximately an 80% reduction in dopaminergic neurons in the substantia nigra pars compacta region of the brain. Damage to neurons in this region disrupts the regulation of movements and leads to the onset of Parkinson's disease. A decrease in dopamine levels results in the loss of movement fluidity, slowing, and tremors (Fahn 2003). The four main descriptive features of Parkinson's disease are resting tremor, rigidity, bradykinesia, and impaired postural reflexes. These symptoms typically begin subtly and progress asymmetrically. Despite clinical tests used in the diagnosis of Parkinson's disease, there is no biological marker to clarify the diagnosis (Pallone 2007).

Walking on all fours is extremely balanced and comfortable, while walking on two feet becomes difficult and requires flawless neuronal control (Güler 2011). Superior brain control is necessary for a person to be able to progress in the designated direction and speed and to cope with external influences. Without superior brain control, only basic balance and stepping responses can be generated at the spinal cord level (Burke *et al.* 2001). In order to walk for long periods without fatigue, the brain, spinal cord, nerves, muscles, bones, and joints must work together in harmony, and the timing and strength of joint and muscle movements must be appropriate. Additionally, receiving accurate and timely feedback about body position and speed is important for walking. Any problem that disrupts this balance increases energy requirements and affects walking (Yavuzer 2014). Gait analysis presents this information in numerical values by examining the muscles and skeletal system, normal walking characteristics should be known for accurate diagnosis and treatment, pathological conditions should be distinguished, and the causes affecting walking should be understood (Cimolin and Galli 2014). Gait analysis is widely used, especially in fields such as orthopedics, neurology, and sports medicine, to assess health conditions (Akalan and Temelli 2014).

Artificial neural networks (ANN), inspired by the biological nervous system of humans, are sophisticated mathematical models capable of learning and decision-making based on acquired knowledge. This advanced computational method learns complex relationships between events and data by analyzing the data samples provided to the system. The learning process enables the system to make logical and accurate decisions when faced with new situations or examples that it has not encountered before, by utilizing the knowledge and experiences gained in the past. The ability of artificial neural networks to perform these tasks makes them valuable tools in various fields such as data classification, prediction, and pattern recognition. These systems can identify complex relationships and patterns through provided examples, thereby making informed predictions in new scenarios they encounter (Öztürk and Şahin 2018).

There are many studies in the literature that utilize artificial neural networks for the classification of neurodegenerative diseases. One such study conducted by Kaczmarczyk *et al.* (2009) investigates the accuracy of three different models in classifying the gait patterns of post-stroke patients. These methods include qualitative analysis of gait kinematics, as well as two different quantitative research types: minimum and maximum joint angle values, and the progression of all joint angle changes. The study concludes that ANN analysis is superior to the other two methods (qualitative variable analysis and min/max joint angle analysis) in classifying the gait patterns of post-stroke patients, dividing them into three types.

Erdaş et al. Berke Erdaş *et al.* (2022) conduct a study to test the accuracy of deep learning-based classification of ALS, Huntington's, and Parkinson's patients using walking parameters. In the study, one-dimensional walking data and the conversion of one-dimensional data into rapid response codes result in two-dimensional data. It is stated that the obtained data performs well in classification with convolutional neural networks. Shi *et al.* (2022) use IMU sensors to detect freezing of gait in Parkinson's patients during walking. In the study, convolutional neural networks are used to detect freezing of gait with the obtained data. The study concludes that it achieves high accuracy in detecting freezing movements. Prabhu et al. Prabhu *et al.* (2020), aiming to overcome the limitations of traditional Fourier analysis, investigate the dynamics of human walking by adopting Recurrence Quantification Analysis (RQA). It is found that RQA is an effective analysis tool for non-linear and non-stationary data.

In the study, Support Vector Machine (SVM) and Probabilistic Neural Network (PNN) are used to classify walking signals of individuals with neurodegenerative diseases such as ALS, Huntington's, and Parkinson's, including 13 patients and 13 healthy control individuals, with two different classification models. Binary classification results using SVM and PNN show accuracy rates ranging from 96% to 100%. Setiavan et al. Setiawan *et al.* (2022) design a convolutional neural network (CNN) to classify neurodegenerative diseases (NDD) using time-frequency spectrograms of walking force signals, aiming to support physiotherapists in the early diagnosis, effective treatment planning, and monitoring of disease progression. The proposed NDD detection algorithm effectively distinguishes gait patterns between HC and NDD patients, achieving 94.34% sensitivity, 96.98% specificity, 96.37% accuracy, and 0.97 AUC value using 5-fold cross-validation.

Yücelbas C. and Yucelbas S. Yücelbaş and Yücelbaş (2019) mention in their study that using the ANN algorithm for the statistical classification of walking analysis data in Parkinson's disease proves successful. Balaji et al. Balaji *et al.* (2020) demonstrate in their study, where they diagnose and stage 93 Parkinson's patients and 73 healthy individuals using machine learning with walking parameters, that they achieve accuracy rates ranging from 76% to 100%. Shetty and Rao Shetty and Rao (2016) show in their study, where they perform machine learning on Parkinson's, ALS, and Huntington's patients, that they achieve an accuracy rate of 83% and can differentiate between different diseases. In the study conducted by Akgün et al., where ALS patients' walking signs are trained using the ANN model for disease diagnosis, 13 normal and 13 ALS patient individuals are included. The study explains that a success rate of 87.5% is achieved in distinguishing ALS patients.

Neurodegenerative diseases such as ALS, Huntington's disease, and Parkinson's disease pose significant challenges in diagnosis and management due to their complex and progressive nature. Gait analysis has emerged as a valuable method for assessing motor function and detecting subtle changes indicative of these conditions. The aim of this study is to innovate disease diagnosis by leveraging the power of artificial neural networks, specifically the ANN algorithm, to analyze walking parameters associated with ALS, Huntington's, and Parkinson's diseases. Our approach seeks to diagnostic processes by providing a quick and easy-to-use tool for clinicians to differentiate between pathological and healthy gait patterns.

METHOD

Data

In this study, data was obtained from the PhysioNet website (Hausdorff *et al.* 2000). The obtained data from ALS patients were collected from the Neurology Clinic at Massachusetts General Hospital. Records from patients with Parkinson's disease (n = 15), Huntington's disease (n = 20), or ALS (n = 13) were obtained from this database. Records from 16 healthy control subjects were also included. Subjects were instructed to walk at their normal speed in a 77 m corridor for 5 minutes. A force-sensitive insole was placed in the subject's shoe to measure the walking rhythm and timing of the walking cycle. With this information, the step duration or the duration of the walking cycle (the time from the first contact of one foot to the subsequent contact of the same foot) was determined for each step. The average walking speed of each subject was also determined by dividing the total distance walked by the walking time.

The collected data consists of walking speed, walking duration, and turn durations for the right and left legs. The obtained data form a dataset with 16 healthy data, 15 Parkinson's patient data, 20 Huntington's patient data, and 13 ALS patient data. For input data, the last 4 data of each dataset were defined as a separate matrix for testing. Accordingly, a single-column matrix consisting of 14 data for healthy subjects, 11 data for Parkinson's patients, 16 data for Huntington's patients, and 9 data for ALS patients was created. This matrix will be provided to the ANN as a 6-input input data.

For output data, a single column was created where the number 1 corresponds to healthy data, 2 to Huntington's data, 3 to Parkinson's data, and 4 to ALS data. Test data was separated as described above and arranged in a single column matrix, with four data groups arranged vertically. Test output data was created in the same manner as the input data, arranged in groups of four in a single column matrix.

ANN Model

The purpose of the modeling stage in this application is to diagnose whether the input data obtained from walking parameters belong to the healthy group, Huntington's patients, Parkinson's patients, or ALS patients. In this study, ANN algorithms including the Levenberg-Marquardt Algorithm, Bayesian Regularization Algorithm, and Scaled Conjugate Gradient Algorithm were compared and used in the diagnosis differentiation. At the end of the training, the relationship between success rate and algorithm in disease determination is established. An ANN model was created using Neural Network Training Tool in MATLAB. The ANN model was designed with 6 inputs, 10 hidden layers, and 1 output (Figure 1).

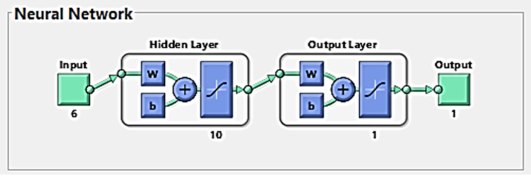

Figure 1 ANN structure of the model.

The performance function has been determined as Mean Square Error (MSE). A neural network with 2 layers has been constructed, with 100 hidden layers and 10000 epochs. Below, the training results for the Levenberg-Marquardt, Bayesian Regularization, and Scaled Conjugate Gradient algorithms are shown in Figures 2-10.

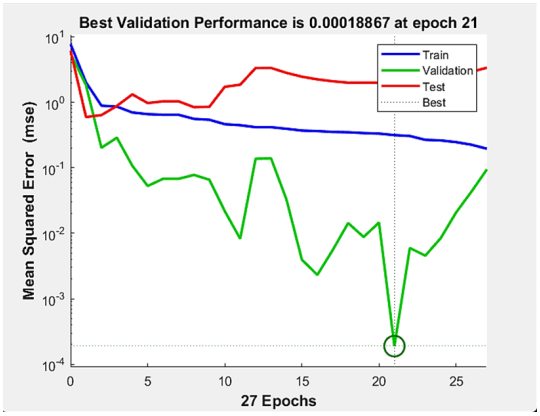

Figure 2 The performance graph for the Scaled Conjugate Gradient Algorithm.

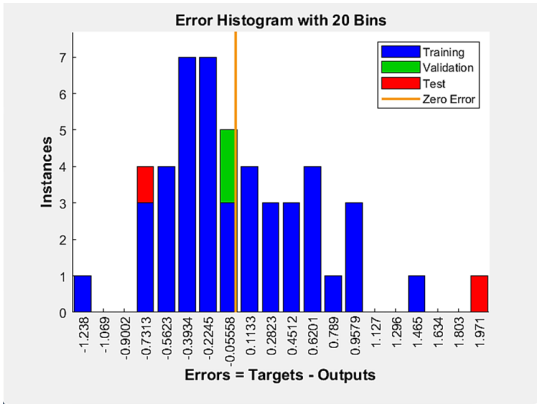

Figure 3 The distribution of error rates for the Scaled Conjugate Gradient Algorithm.

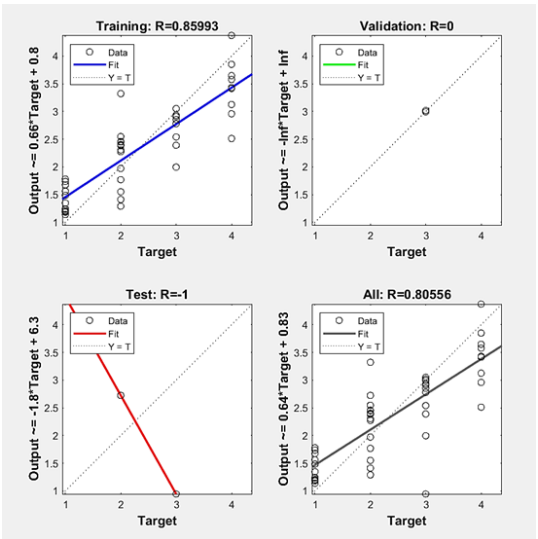

Figure 4 The regression graph for the Scaled Conjugate Gradient Algorithm.

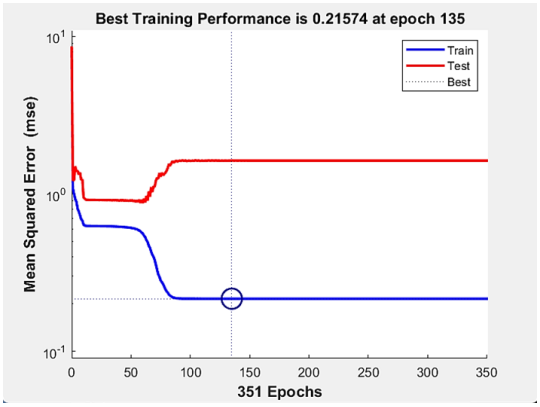

Figure 5 The performance graph for the Bayesian Regularization Algorithm.

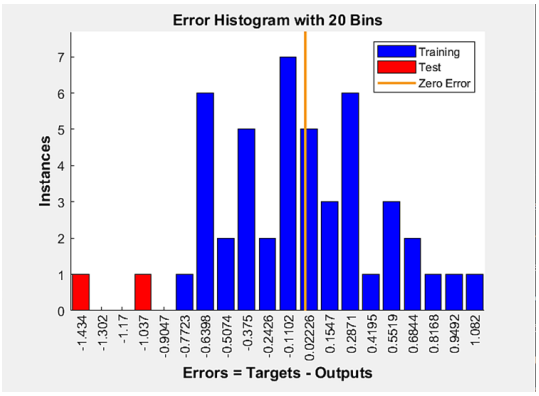

Figure 6 The error distribution graph for the Bayesian Regularization Algorithm.

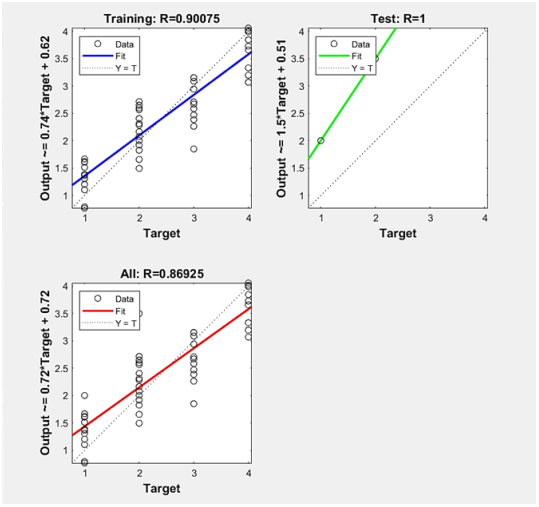

Figure 7 The regression graph for the Bayesian Regularization Algorithm.

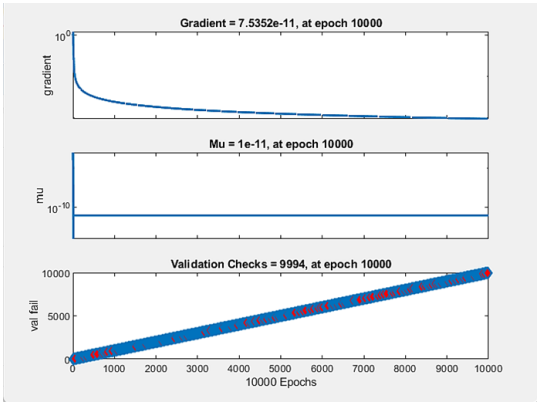

Figure 8 The training graph for the Levenberg-Marquardt Algorithm.

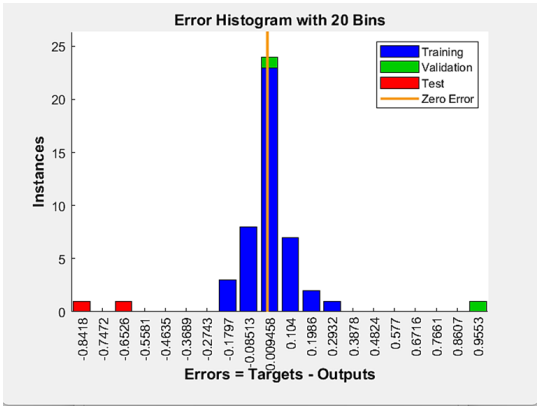

Figure 9 The distribution of error rates for the Levenberg-Marquardt Algorithm.

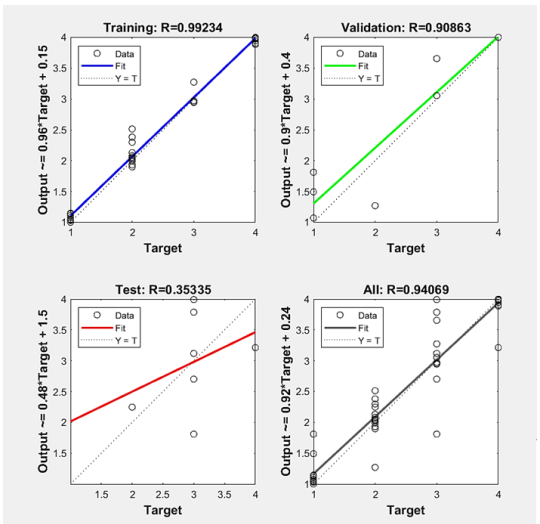

Figure 10 The regression graph for the Levenberg-Marquardt Algorithm.

RESULTS

In the diagnosis of neurodegenerative diseases such as ALS, Parkinson's, Huntington's, and healthy individuals, attempts were made to determine the disease using an ANN model based on walking parameters, and success rates were compared among ANN algorithms. The success rates of the algorithms used in the diagnosis of neurodegenerative diseases are as follows: Levenberg-Marquardt algorithm achieves 99%, Bayesian Regularization algorithm achieves 90%, and Scaled Conjugate Gradient algorithm achieves 85% success rate (Figure 11).

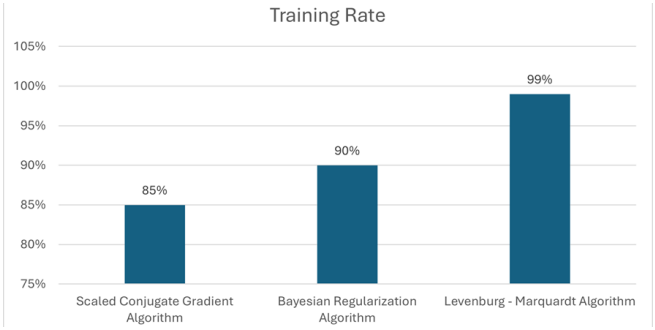

Figure 11 The success rates of the algorithms.

The Levenberg-Marquardt Algorithm is considered to provide the most successful diagnosis among the algorithms, with a success rate of 99%. When comparing the results of the study between the test and training datasets, it is observed that while the training data exhibit high success rates, the test data show lower success rates. This discrepancy is attributed to overfitting in the ANN algorithms due to the limited amount of data, indicating that the training did not achieve high performance. Therefore, it is suggested that future studies should utilize larger datasets to address this issue.

CONCLUSION

In this study, we explored the potential application of artificial neural networks (ANNs) for diagnosing neurodegenerative diseases based on walking parameters. Our findings demonstrate that ANNs, particularly utilizing the Levenberg-Marquardt Algorithm, can achieve a remarkable 99% success rate in disease diagnosis among individuals with ALS, Parkinson's, Huntington's, and healthy controls. This highlights the significant promise of ANNs as valuable tools in early disease detection and clinical decision-making.

While our study focused on walking parameters, the potential of ANNs extends to broader applications within neurodegenerative disease diagnostics. Future research could explore the integration of additional physiological, imaging, and genetic data into ANN models to enhance diagnostic accuracy and facilitate personalized treatment strategies. Furthermore, the successful implementation of ANNs in this context underscores the need for collaborative efforts between clinicians, data scientists, and engineers to translate innovative technologies into clinical practice. Establishing robust, validated ANN models for neurodegenerative disease diagnosis requires interdisciplinary collaboration and rigorous validation against diverse patient cohorts.

Availability of data and material

Not applicable.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Ethical standard

The authors have no relevant financial or non-financial interests to disclose.

LITERATURE CITED

Akalan, N. E. and Y. Temelli, 2014 Serebral parezide gözlemsel yürüme analizinin yeri ve kullanılabilirliği. Sağlık Bilimleri ve Meslekleri Dergisi **1**: 28–45.

Aslan, D. H., M. E. Hernandez, M. L. Frechette, A. T. Gephart, I. M. Soloveychik, *et al.*, 2021 The neural underpinnings of motor learning in people with neurodegenerative diseases: A scoping review. Neuroscience Biobehavioral Reviews **131**: 882–898.

Balaji, E., D. Brindha, and R. Balakrishnan, 2020 Supervised machine learning based gait classification system for early detection and stage classification of parkinson's disease. Applied Soft Computing **94**: 106494.

Bart, v. V., 2018 *Variability in neuromotor control of the musculoskeletal system dynamics: a stochastic modelling approach*. Ph.D. thesis.

Bates, G. P., R. Dorsey, J. F. Gusella, M. R. Hayden, C. Kay, *et al.*, 2015 Huntington disease. Nature Reviews Disease Primers **1**: 15005.

Berke Erdaş, , E. Sümer, and S. Kibaroğlu, 2022 Cnn-based severity prediction of neurodegenerative diseases using gait data. Digital Health **8**: 20552076221075147.

Burke, R. E., A. M. Degtyarenko, and E. S. Simon, 2001 Patterns of locomotor drive to motoneurons and last-order interneurons: clues to the structure of the cpg. Journal of Neurophysiology **86**: 447–62.

Cimolin, V. and M. Galli, 2014 Summary measures for clinical gait analysis: A literature review. Gait Posture **39**: 1005–1010.

Fahn, S., 2003 Description of parkinson's disease as a clinical syndrome. Annals of the New York Academy of Sciences **991**: 1–14.

Güler, H. C., 2011 Yürüyüş analizi: Temel kavramlar ve uygulama. In *Fiziksel Tıp ve Rehabilitasyon*, edited by M. Beyazova and Y. G. Kutsal, pp. 401–26, Güneş Tıp Kitabevi, second edition.

Gültekin, M. and A. Ekinci, 2017 Huntington hastalığında dikkat fonksiyonlarının değerlendirilmesi. Dicle Tıp Dergisi **44**: 365–71.

Hausdorff, J. M., A. Lertratanakul, M. E. Cudkowicz, A. L. Peterson, D. Kaliton, *et al.*, 2000 Dynamic markers of altered gait rhythm in amyotrophic lateral sclerosis. Journal of Applied Physiology **88**: 2045–2053.

Kaczmarczyk, K., A. Wit, M. Krawczyk, and J. Zaborski, 2009 Gait classification in post-stroke patients using artificial neural networks. Gait Posture **30**: 207–210.

Kaya, A. and F. Özcan, 2017 Amiyotrofik lateral skleroz (als) hastalarıyla iletişim ve güncel teknolojiler. The Journal of Turkish Family Physician **8**: 43–48.

Marsden, C. D., 1994 Parkinson's disease. Journal of Neurology, Neurosurgery and Psychiatry **57**: 672–681.

McColgan, P. and S. J. Tabrizi, 2018 Huntington's disease: a clinical review. European Journal of Neurology **25**: 24–34.

Pallone, J. A., 2007 Introduction to parkinson's disease. Disease-a-month **53**: 195–199.

Prabhu, P., A. K. Karunakar, H. Anitha, and N. Pradhan, 2020 Classification of gait signals into different neurodegenerative diseases using statistical analysis and recurrence quantification analysis. Pattern Recognition Letters **139**: 10–16.

Setiawan, F., A. B. Liu, and C. W. Lin, 2022 Development of neurodegenerative diseases' gait classification algorithm using convolutional neural network and wavelet coherence spectrogram of gait synchronization. IEEE Access **10**: 38137–38153.

Shetty, S. and Y. S. Rao, 2016 Svm based machine learning approach to identify parkinson's disease using gait analysis. In *2016 International Conference on Inventive Computation Technologies (ICICT)*, volume 2, pp. 1–5, IEEE.

Shi, B., A. Tay, W. L. Au, D. M. Tan, N. S. Chia, *et al.*, 2022 Detection

of freezing of gait using convolutional neural networks and data from lower limb motion sensors. IEEE Transactions on Biomedical Engineering **69**: 2256–2267.

Turner, M. R. and M. Benatar, 2015 Ensuring continued progress in biomarkers for amyotrophic lateral sclerosis. Muscle Nerve **51**: 14–18.

Yavuzer, G., 2014 Yürüme analizi ve temel kavramlar. Türk Ortopedi ve Travmatoloji Birliği Derneği Dergisi **13**: 304–308.

Yuldashev, U., 2022 Correlation networks of spinal motor neurons that innervate lower limb muscles during a multi-joint isometric task. The Journal of Physiology .

Yücelbaş, C. and Yücelbaş, 2019 Çift yoğunluklu 1-d dalgacık dönüşümü kullanılarak parkinson hastalığının yaş faktörüne göre tespit edilmesi. Avrupa Bilim ve Teknoloji Dergisi pp. 881–887.

Öztürk, K. and M. E. Şahin, 2018 Yapay sinir ağları ve yapay zekâ'ya genel bir bakış. Takvim-i Vekayi **6**: 25–36.

How to cite this article: Derdiyok, F. B., and Serbest, K. ANN Algorithms for Parkinson's, ALS, Huntington, and Healthy Walking Detection. *Computers and Electronics in Medicine*, 1(1), 18-23, 2024.