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Araştırma Makalesi Research Article

ANN BASED EARLY DETECTION OF ALZHEIMER DISEASE ON SELECTED FEATURES

Seyit Gazi YILDIZ[1], Kazım YILDIZ[2*]

[1]Marmara University, Institute of Pure and Applied Sciences, Computer Enginering, Istanbul, Turkey
[2]Marmara University, Faculty of Technology, Department of Computer Engineering, Istanbul, Turkey

Keywords

Alzheimer Disease,
ANN,
Artificial Neural Networks,
Machine Learning,
Mild Cognitive Impairment.

Abstract

Alzheimer's Disease (AD) is a type of dementia, also called cognitive impairment. In cases where measures are not taken against the disease, it may result in a decrease in the quality of life of the person and result in very serious consequences. While it presents with neurological consequences such as decreased functions of thinking and memory, it may result in death in advanced cases. The fact that the treatment is not completely possible makes the place of early diagnosis and intervention important for AD. As a result of the researches carried out in the study, it was seen that there are many studies and scientific content within the framework of AD. A method for early diagnosis of the disease was evaluated by using an open source shared dataset, which includes some disease-specific values and demographic characteristics. By using Artificial Neural Networks (ANN) model, which is one of the machine learning methods, it is aimed to be useful for other studies to take precautions for early detection of the disease. With the ANN, which was classified as dementia and non-dementia individuals, Root Mean Square Error (RMSE) value 0.2302, Mean Absolute Error (MAE) value 0.1899 and accuracy rate of 98.5% was obtained.

SEÇİLMİŞ ÖZELLİKLER ÜZERİNDEN ALZHEİMER HASTALIĞININ YSA TABANLI ERKEN TEŞHİSİ

Anahtar Kelimeler

Alzheimer Hastalığı,
YSA,
Yapay Sinir Ağları,
Makine Öğrenmesi,
Hafif Bilişsel Bozukluk.

Öz

Alzheimer Hastalığı(AH), bilişsel bozukluk olarak da adlandırılan bir tür demans hastalığıdır. Hastalığa karşı önlem alınmadığı durumlarda kişinin yaşam kalitesinde düşüşlere sebep olurken çok ciddi sonuçlarla neticelenebilir. Hastalıkla birlikte kişide düşünme ve hafıza yetisini kullanma fonksiyonlarında azalma görülebilir. Nörolojik sonuçlarla karşımıza çıkabileceği gibi, ileri durumlarda ölümle sonuçlanabilir. Tedavinin tam anlamıyla mümkün olmaması, AH için erken teşhis ve müdahalenin yerini önemli kılıyor. Çalışmada yapılan araştırmalar sonucunda, AH çerçevesinde birçok çalışma ve bilimsel içeriğin olduğu görülmüştür. Hastalığa özgü bazı değerlerin ve demografik özelliklerin yer aldığı açık kaynak olarak paylaşılmış veri seti kullanılarak, hastalığın erken teşhisine yönelik bir yöntem değerlendirilmiştir. Makine öğrenmesi yöntemlerinden Yapay Sinir Ağları (YSA) modeli kullanılarak, hastalığın erken tespiti yönünde önlemlerin zamanında alınmasına yönelik yapılacak diğer çalışmalara yararlı olması hedeflenmiştir. Demans ve demans olmayan birey şeklinde sınıflandırması yapılan Kök Ortalama Kare Hatası (KOKH) değeri 0.2302, Ortalama Mutlak Hata (OMH) değeri 0.1899 ve %98.5 doğruluk oranı elde edilmiştir.

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Yazar Kimliği / Author ID (ORCID Number)
S. G. Yıldız, 0000-0002-2708-2486
K. Yıldız, 0000-0001-6999-1410

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* İlgili yazar / Corresponding author: seyityildiz@marun.edu.tr, +90-216-577-84-00

ANN BASED EARLY DETECTİON OF ALZHEİMER DİSEASE ON SELECTED ALZHEİMER FEATURES

Seyit Gazi YILDIZ[1], Kazım YILDIZ[2†]
[1]Marmara University, Institute of Pure and Applied Sciences, Computer Enginering, Istanbul, Turkey
[2]Marmara University, Faculty of Technology, Department of Computer Engineering, Istanbul, Turkey

Highlights

- This study aims to classify Alzheimer's patients and healthy individuals with using selected features
- The dataset contains 9 different features.
- The results of the study were obtained using the ANN algorithm.
- The system evaluated the accuracy rate as a result of the test data as an average of 98.5%, the RMSE value as 0.2302 and the MAE value as 0.1899.

Purpose and Scope
The aim of this study is to contribute to other literature studies for the early diagnosis of the disease by using the ANN algorithm with the dataset of selected features seen in Alzheimer's disease. Considering that the disease is difficult to detect and results in death outcomes at advanced levels, it is predicted that early detection of the disease will be a useful evaluation.

Design/methodology/approach
A total of 334 rows of data were used in the system designed by choosing the ANN model, one of the machine learning methodologies, within the scope of the study, together with the literature review. By accepting the approach of the importance of early diagnosis in the disease, the system was trained with a data set that includes demographic structure and some disease characteristics specific to Alzheimer's disease. 80% of the dataset was used for training and 20% for testing. The Cross Entropy Loss function is used to optimize the neural network to keep the loss at low levels before training the system. Torch seed value was determined as 20 and the system was trained in 20 repetitions. The output of whether the person is disease or healthy is obtained.

Findings
Within the study, the system has a structure that classifies people as disease or healthy. Train Accuracy value was determined as 99.63%. In addition, as a result of training the system with test data, Nondemented has successfully completed the classification step with 97.62% and Demented 100.00% accuracy rates. The system's margin of error decreased. It is therefore considered succesful. In addition, the loss value remained constant after a certain point. It is thought that more accurate outputs can be obtained by classifying the system in different options using more data. As a result, an average of 98.5% accuracy rate, RMSE value 0.2302 and MAE value 0.1899 was achieved in the system where the ANN model was applied.

Originality
Includes classification for Alzheimer's patients. As a result of the study, the accuracy rate was determined and compared with the results obtained in similar studies. The fact that it is a study in the direction of early detection of Alzheimer's disease in the study, which includes disease-specific features, expresses its original value.

† Corresponding author: seyityildiz@marun.edu.tr, +90-216-577-84-00

1. Introduction

Alzheimer is a neurological disease which is a type of dementia disease that causes the destruction of brain cells. It is common today, can be more noticeable in older ages. If no action is taken for Alzheimer, it can progress quickly. Additionaly it affects the quality of life, it brings many negative consequences. Alzheimer is a death disease that can cause a decrease in functions such as memory, thinking and behavior. It may occur step by step with the advancing age, and it may take until later ages to reach advanced stages. In this regard, it has become important to predict this disease, for which early diagnosis is very important, with machine learning. AD is one of the types of dementia, also known as Mild Cognitive Impairment (MCI), which is a disease that is difficult to detect and results in fatal outcomes and is assessed as a result of test results (Sertkaya and Ergen, 2022). MCI is known as a transitional phase between age-related cognitive changes and AD (Evyapan Akkuş and Güler, 2016). While one of the factors that increase the risk of the disease is considered to be vitamin deficiency, AD can be seen in individuals with vitamin B12 deficiency or it negatively affects the disease process (Delikanlı Akbay, 2019). Early diagnosis and accuracy have an important place in eliminating the symptoms of the dieased person. Also, Proximal Support Vector Machine (PSVM), K Nearest Neighbour (KNN) and Multilayer ANN methods were found useful in terms of comparing different classification methods, and it was said that the visuals in phase stages were successful in assesing the significance (Tufail et al., 2012). It has been mentioned that a person with dementia, which is evaluated as a syndrome associated with memory loss with a different definition, will have difficulties in performing daily activities, behavior, thinking and memory skills. Multiple classification methodologies were used in this study for the diagnosis of AD and Parkinson's disease (PD). Images scanned by Positron Emission Tomography (PET) were used. In the study, in which SVM, DT and Naive Bayes classification methods were also used, ANN was evaluated as a method that gives a better accuracy rate than other tools with 93.14% (Nancy Noella and Priyadarshini, 2020). Dementia becomes the main factor of Alzheimer's disease by killing the synapses in the following years. It makes people unable to think, read and use many different abilities. A study was carried out using the dataset of the Open Access Series Of Imaging Studies (OASIS), the main aim of which was to identify dementia in various people. The results of the system were discussed by using Support Vector Machine (SVM) and Random Forest (RF) for estimation. As a result, it was found that SVM outperformed other modules and this method was proposed for rapid detection of dementia (Salunkhe and Chavan, 2022). It is difficult to detect, together with symptoms that will prevent recovery to normal health, and the lack of a definitive treatment method shows that the disease is serious. In this context, by emphasizing the widespread use of Magnetic Resonance Imaging (MRI) technology was highlighted and the studies using this technique were examined (Özkaya and Cebeci, 2022). Another study on MRI, although focusing on MRI, evaluated studies that included cerebrospinal fluid biomarkers and positron emission tomography in addition to this method were evaluated (Falahati et al., 2014). A Long Short-Term Memory (LSTM) based model has been proposed for AD, which is considered to be one of the diseases that may arise from cell or intermolecular communication (Işık, 2022). Emphasing that it is a chronic disease, it is not possible to completely treat the disease, and SVM, ANN, Deep Learning (DL) from machine learning methods were analyzed to evaluate the more effective method for diagnosing the disease (Mahajan et al., 2020). In the study, which compares the collective feature selection approaches with the aim of creating a model that predicts the disease, the Normal (CN), MCI and AH dataset, which consists of three main classes, was used. Using the inhomogeneous ensemble feature selection approach together with data mining algorithms, it was the RF method with a higher performance of 91% (Buyrukoğlu, 2021). There are many imaging techniques used to diagnose the disease. In a study made with MRI technique, a total of 6400 MR images were used together with AlexNet, MobileNetV2 architectures and Convolutional Neural Networks (CNN) model for the diagnosis of the disease. Feature selections were made with the Neighborhood Component Analysis (NCA) algorithm, and the model was completed by classifying with SVM. 100% accuracy rate was obtained in the model (Karabay and Çavaş, 2022). In another study using brain cortical and genetic characteristics in classifying the disease, the best results were obtained with Decision Trees (DT) and SVM methods (Yuan et al., 2022). It has been mentioned that ANN, which is emphasized to have a good capacity in terms of classification, is a good method that can be used in studies (Quintana et al., 2012). In another study, which includes some similar features in the dataset to be used in our study, successful results were obtained in SVM. As a result of the study, is thought that it can help people get early treatment for AD (Neelaveni and Devasana, 2020). In the study of Kour et al. (2019) which was conducted with a dataset containing similar AD features, and where accuracy, F-score and RMSE measurements were evaluated, it was observed that Adaptive Neurofuzzy Inference System (ANFIS) was trained for 100 terms and ANN was trained

for 1000 terms, and ANFIS measurements were higher than ANN. Developing a new AD diagnostic model with a different approach than existing studies, Sun et al. (2022) obtained the area under the curve (AUC) value of 0.953 and accuracy value of 0.914 by using the ANN model with the data they accessed from the Gene Expression Omnibus (GEO) database. Again with a different approach, in the study of Aljović et al. (2016), it was stated that an accurate classification was made by using biomarkers in the cerebrospinal fluid together with the ANN methodology, with an accuracy of 95.5% with demented test data and 91.43% with nondemented test data. In the study, the material and method are explained in the second part. The methods used and the dataset are presented with their properties. In addition, the architecture for classification, which describes the working logic of the system, is also included. In the third and last part, the results are shared and comparative analyzes are given.

2. Material and Method

This section provides information on the dataset and methodology which is used in the study.

2.1. Dataset

Within the scope of the study, the Dinçer (2018) dataset containing the characteristics of the disease was used in the context of AD, which is widely used in disease detection. The dataset was created open to three different types of classification: Nondemented, Demented and Converted. As we wanted to get a binary output as a result of our study, only the nondemented and demented samples were taken. In addition, when creating the W weight parameter, the learning will not be fully realized as the same result will be obtained for the layers when the input parameters are 0 (Kızrak, 2018). Therefore, adjustments were made in cases where the disease features in the dataset were marked as 0. The changes were made manually on excel. First, the dataset to be used in the estimation method was prepared. The rows with the corresponding 0 or non-correlated values of the field have been changed to 0.000001 in the dataset. Rows with Converted classification have been deleted so that binary classification can be made. A total of 336 rows were obtained and the dataset was made ready. The characteristics of the disease used in the dataset are given in Table 1 along with their abbreviations.

Table 1. Alzheimer features dataset explanations (Dinçer, 2018)

Abbreviations	Alzheimer Features
Gender	Gender
Age	Age
EDUC	Years of Education
SES	Socioeconomic Status
MMSE	Mini Mental State Examination
CDR	Clinical Dementia Rating
eTIV	Estimated total intracranial volume
nWBV	Normalize Whole Brain Volume
ASF	Atlas Scaling Factor
Class	Label of class

2.2. Artificial Neural Networks (ANN)

For the purposes of early detection of the disease, artificial neural network was utilized in this study. ANN is a self-organized machine learning method that can learn and evaluate. This method, which can be trained and adapted, works by modeling the learning structure similar to the human brain. In this way, it is aimed to train machines with the ANN method, as in humans, to make their own decisions. An example of the perceptron, which is the smallest part of the artificial neural network shown in Figure 1, is given. The smallest part of artificial neural networks is called perceptron. Figure 1 is visualized again based on the model with the perceptron sample used in (Kızrak, 2018).

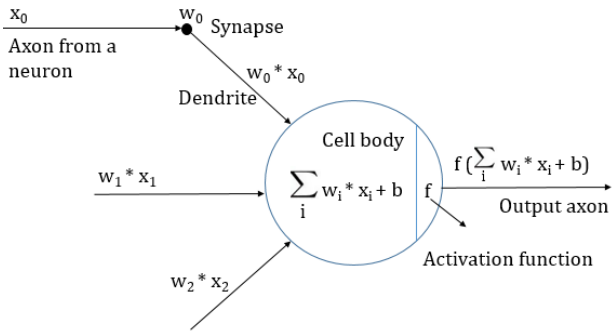

Figure 1. Perceptron Example (Kızrak, 2018)

While the Perceptron is expressed with a linear function as in equation 1, Frank Rosenblatt first defined this function in 1957. y represents the score of the input. It is a dependent variable because it depends on the value of x. x is input and argument. W refers to the weight parameter and b bias value (Kızrak, 2018).

$$y = (W * x) + b \qquad (1)$$

In the ANN model, the goal is to calculate the W and b values that will give the best score in the model. ANN model; It consists of 3 layers: Input, Hidden and Output Layer. These layers are given in Figure 2 and Figure 3 which were visualized again based on the model in which the layers of the ANN algorithm used in Kızrak (2018) were shown. Each round in Figure 2 and Figure 3 represents neurons.

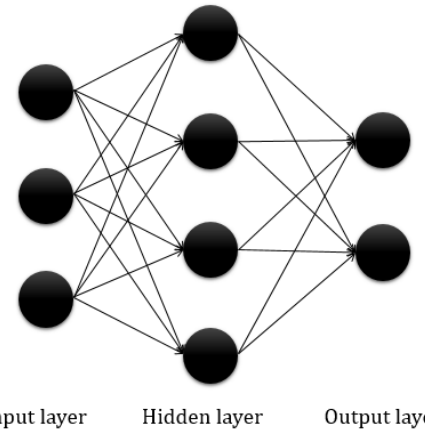

Figure 2. Example of Single Layer ANN Layers (Kızrak, 2018)

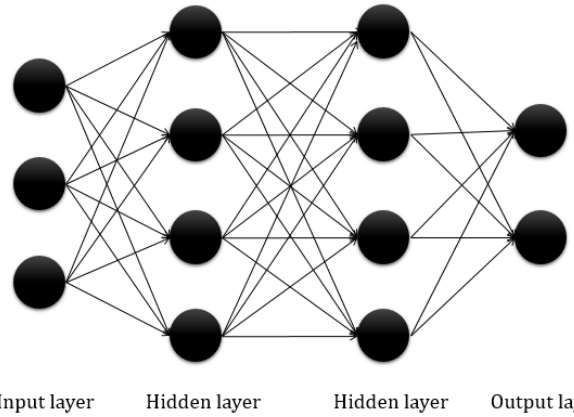

Figure 3. Example of Multi-Layer ANN Layers (Kızrak, 2018)

While finding the total weight, each layer is multiplied by the next and these multiplied values are added together. The bias value is obtained by summing each input/output value on the hidden and output layers. In the single-layer ANN model described in Figure 2, there are a total of 6 neurons apart from the input layer. The total weight is calculated as (3*4)+(4*2)=20. The bias value is obtained as 4+2 = 6 with the hidden and output layer. Widrow and Hoff were the first to work on the multilayer ANN model in 1960. In the multi-layer ANN model described in Figure 3, there are a total of 10 neurons apart from the input layer. The total weight value is obtained as (3*4) +

(4*4) + (4*2) = 36. The bias value is obtained as 4+4+2 = 10. In addition, the multilayer ANN model has two hidden layers. In the multiple ANN model in Figure 3, there are 46 parameters to be learned, 36 + 10 = 46 in total (Kızrak, 2018).

Layers and neurons in layers have an indirect effect on the model. The neurons within the layer are not related to each other. The system works by transferring the information from the previous layer trained to the next layer. The neurons in the two sequential layers affect each other with their own values and perform a transfer in determining the learning level of the model. The number of neurons in a layer is one of the factors affecting the performance of the system. The influence of many different parameters affects the performance at the output. In cases where the input value (x value) is '0', W * x = 0 and + b value offsets the output of the score function. This allows the model to continue the learning process in the next step. W weight vector should be the number of neurons, and b values should be the number of neurons in the next layer (Kızrak, 2018).

In the studies, RMSE and MAE metrics are used to evaluate the performance of the models that occur regularly (Chai and Draxler, 2014). After the system was trained, equation 2 for RMSE and equation 3 for MSE were applied based on the formulas used in their studies (Chai and Draxler, 2014; Acharya 2021).

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - y')^2} \qquad (2)$$

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}|y_i - y'| \qquad (3)$$

Errors represent the differences between the estimated values and the actual values. Among the expressions in the formulas, y_i refers to the actual value, y' refers to the prediction value and n refers to the number of observations (Acharya, 2021). Inspired by the example in Köseoğlu (2021) 's review of model performance, metrics were obtained according to these formulas at the end of the study.

2.3. Architectural Structure in Classification

The architectural structure of the application, which was prepared using the dataset described in 2.1 and the method specified in 2.2, works as indicated in Figure 4. After the system has been trained, the structure that decides whether the person is disease or not is visualized by allowing it to predict. Inspired by the visual in Figure 3 prepared within the scope of the study prepared by Klumpp et al. (2018), the diagram was redrawn and expressed according to the flow mechanism in this study. The system made in this study was inspired by the model applied within the scope of the study by Gerontogianni (2022). The system was completed using python language on Pycharm ide. It was run on the Windows operating system. The system was trained with the ANN model using some Alzheimer's disease-specific disease characteristics together with the demographic structure. The torch library was used to create the ANN model. 80% of the dataset was used for training and 20% for testing. The sklearn library was used for training, preparing test data and analyzing results. The sklearn library was also used in the calculation of RMSE and MAE values. The Cross Entropy Loss function is used to optimize a deep neural network by minimizing loss before training the system. Torch seed value is set to 20. The system was trained in 20 repetitions. Depending on the result of training the system, the loss function graph in Figure 5 is output with the help of the matplotlib library. When the test data is run in the trained system, two outputs meet us according to the classification logic shown at the end of the architectural structure. As the output, it predicts whether the person has AD or not.

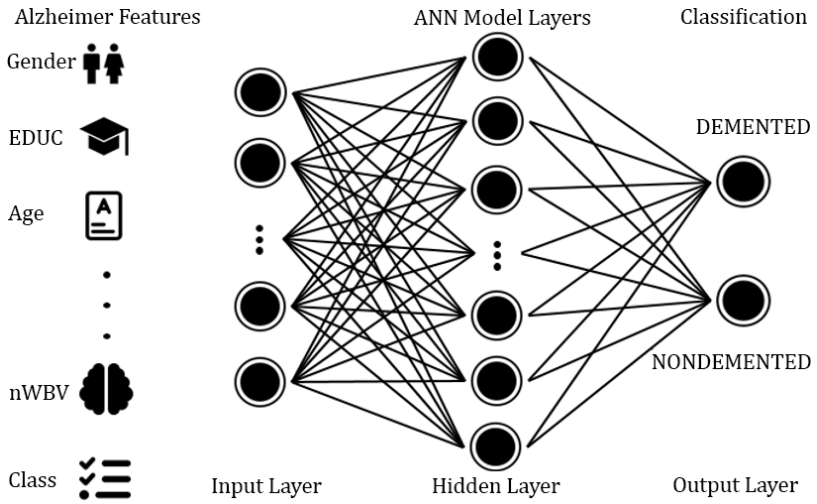

Figure 4. Data Flow Diagram in Classification Model (Klumpp et al., 2018)

3. Results

In order to contribute to universal studies, it is predicted that it will be a useful evaluation in the early detection of the disease, taking into account the advantages of preventing the progression of the disease in the early diagnosis of this disease, which can result in fatal results, and the high cost and difficult to detect factors. As a result of the early diagnosis of the disease within the scope of the research, it is aimed to record a certain stage by detecting the disease before it moves to advanced stages. As a result of each repetition, the loss and train accuracy values are shown in the graph in Figure 5. While the Loss value was 1.16923773 and 1.16919613 in the first 2 iterations, it gave the output of 1.16915369 with the third iteration. It was observed that this result did not change in each training repetition. The decrease in the margin of error can be interpreted as a successful behavior of the system. However, if it remains constant after a certain point, the fact that the diversity in the data is low and the system has a binary classification can be interpreted as a negative effect in this sense. This is thought to affect the repetition of the result after a certain point. The graphic output showing the loss function values according to the turnover period is shown in Figure 5. It is seen that the test and training loss values are close to each other. Additionally, the Train Accuracy value was 99.63%. The system successfully completed the test veri by classifying nondemented 97.62% and demented 100.00% accuracy. In the system where the ANN model was applied, the accuracy value obtained as a result of the test data was obtained as 98.5% on average. The accuracy value obtained was slightly below the accuracy value in the study of Kour et al. (2019), where similar parameters in the dataset used in this study were used. Although training 20 epochs were applied in this study, in the study of Kour et al. (2019), model training was completed with the ANN model in the form of 1000 epochs.

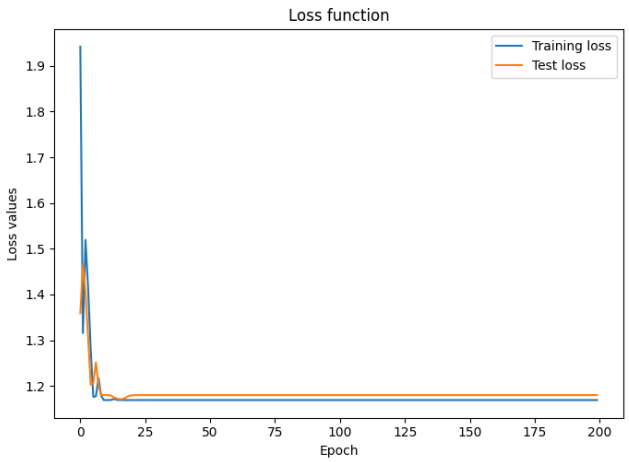

Figure 5. Epoch – Test&Training Loss Function Chart

4. Discussion and Conclusion

As a result of using the dataset used in the study in two categories as training and test data, the system completed the accuracy rate of the prediction data as 98.5%. It has been observed that increasing the Torch seed value decreases the prediction success. When the value of 20 was used, it gave the highest prediction rate. It has been observed that the accuracy rate decreases when 30 and 40 values are used, while the accuracy rate decreases

when 10 and 15 values are used. In the study Karabay and Çavaş, (2022) made with 6400 MR images, a higher value was obtained with the method applied. While 100% accuracy was achieved in the study using the SVM algorithm, the use of MR images and more data in the study can be considered as a factor that increases the reliability of the application. The success rate 92% was achieved in the classification of the disease by using DT and SVM models in the study Yuan et al., (2022), which included different methods together with the dataset containing the brain cortical and genetic characteristics. When the two studies using SVM are compared, considering the data differences, it is seen that the accuracy rates vary in systems with datasets with different characteristics. The high accuracy rate of the ANN algorithm can be considered as a method that can be used in future studies. In the study by Kour et al. (2019), in which similar features were used, the accuracy value 99.4% obtained with the ANN model was higher than this study. For the datasets to be used in the detection of AD, can be expanded by adding different features of the disease in addition to the values used in the study. It can give more reliable and accurate results in a system where other features are combined with MR images. The use of different data types in studies, keeping the data set wider, and achieving high accuracy in addition can be interpreted as factors that will increase the reliability of the system. Comparison of accuracy and RMSE values of some titles similar to the study is given in Table 2. In this context, as a result of the study, high accuracy rates can be obtained for early detection of the disease by using the ANN method.

Table 2. Comparing the accuracy of the studies carried out with the ANN model on different subjects

Contributors	Title of the Study	ANN Accuracy (A) & RMSE Values	Demented (D) & Nondemented (ND) Accuracy
Aljović et al. (2016)	Artificial neural networks in the discrimination of Alzheimer's disease using biomarkers data	A= 93.47% RMSE= 0.1435	D= 95.5% ND= 91.43%
Nancy Noella and Priyadarshini (2020)	Diagnosis Of Alzheimer's And Parkinson's Disease Using Artificial Neural Network	A= 93.14%	-
Kour et al. (2019)	Evaluation of Adaptive Neuro-Fuzzy Inference System with Artificial Neural Network and Fuzzy Logic in Diagnosis of Alzheimer Disease	A= 99.4% RMSE= 0.1435	-
Sun et al. (2022)	Establishment and Analysis of a Combined Diagnostic Model of Alzheimer's Disease With Random Forest and Artificial Neural Network	A= 91.4%	-
In this study	ANN Based Early Detection Of Alzheimer Disease On Selected Alzheimer Features	A= 98.5% RMSE= 0.2302	D= 100.00% ND=97.62%

Conflict of Interest

No conflict of interest was declared by the author.

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