Identification of Multiple Sclerosis Using Artificial Neural Networks

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Abstract

Multiple sclerosis (MS) is a chronic neurological disorder affecting the central nervous system, causing a range of symptoms including vision problems, fatigue, and motor dysfunction. Early and accurate diagnosis is crucial for effective treatment and management of the disease. Magnetic Resonance Imaging (MRI) plays a vital role in identifying MS, but manual interpretation of MRI scans is time-consuming and prone to human error. In this study, we aim to enhance the diagnostic process by employing artificial neural networks (ANNs), specifically Multi-Layer Perceptron (MLP) and Long Short-Term Memory (LSTM) networks, to identify MS from MRI data. The research involves data preprocessing, feature extraction, and model training using neural network architectures. The performance of these models is evaluated based on accuracy, sensitivity, and specificity. The results show that the LSTM model outperforms other methods in terms of diagnostic accuracy, offering a promising tool for MS detection in clinical settings. This work contributes to the integration of machine learning techniques in medical diagnostics and emphasizes the potential of neural networks for improving healthcare outcomes.

Keywords: *MRI, MLP, Sclerosis*

Introduction

Multiple sclerosis (MS) is a debilitating neurological disease affecting the brain and spinal cord. In MS, the immune system attacks the protective sheath (myelin) of nerve tissue, disrupting communication between the brain and other areas of the body. Ultimately, this disease leads to temporary damage or permanent injury to the nerves. The range of symptoms associated with MS is broad, including fatigue and weakness, immobility, vision problems, and motor disturbances. Depending on the affected areas in the brain and nervous system, the type and severity of symptoms and manifestations may vary.

Currently, there is no definitive and specific cause identified for the onset of MS; however, various factors that may play a role in its development include genetic predispositions, geographic location of birth and residence, stress or excessive physical and mental fatigue, exposure to certain microbes and viruses during childhood, low levels of vitamin D in the blood, tobacco use, excessive salt intake, and more.

MS begins in the body when white blood cells, which have a defensive role in the body, mistakenly attack the myelin that protects nerve fibers instead of a foreign agent. Each time these white blood cells attack the nerve fibers connected to one of the patient's limbs, that limb experiences dysfunction. The exact cause of this phenomenon is not yet understood.

Problem statement

One of the most sensitive methods for diagnosing this disease is Magnetic Resonance Imaging (MRI) of the brain and spinal cord, which detects lesions (damaged areas). In this imaging, the characteristics of plaques (white matter) are very important, and factors such as shape, compactness, volume, tissue contrast, and the surrounding area of the plaque must be examined. The results indicate whether a person is affected by this disease or not. Multiple neural networks can be used to diagnose multiple sclerosis (MS). In this research, the existing data regarding MS is first cleaned and then presented to various neural networks after preparation. The learning rate and the method of disease diagnosis for test data will serve as the criteria for evaluating the performance of different neural networks. In this study, we aim to diagnose multiple sclerosis using neural networks.

The research questions are as follows:

1. What parameters influence the onset of multiple sclerosis?

2. How can a neural network be developed with appropriate accuracy for identifying multiple sclerosis?

Main Objective:

• Identification of Multiple Sclerosis (MS) using neural networks.

Secondary Objectives:

• Providing a method to enhance the efficiency (in terms of accuracy, sensitivity, and detectability criteria) of MS diagnosis.

Practical Objectives:

• Health organizations in the country, such as healthcare centers, to expedite the diagnosis of the disease and ensure timely referral of patients to the appropriate treatment departments.

• Statistical organizations in the health sector can extract statistical information regarding the presence or absence of the disease without needing to know the patient's condition, solely based on biological data.

One of the applications of machine learning methods in medicine is the diagnosis of diseases, including multiple sclerosis (MS). This disease affects the central nervous system. In studies related to the diagnosis of MS, some characteristics of a number of MS patients and healthy individuals are provided to classification algorithms. These algorithms can create models for classifying patients into two categories: "MS patients" and "healthy individuals." The created models can be used to classify new patients and individuals suspected of having MS, predicting their disease status or health.

So far, many studies have been conducted in this area of research. This section discusses some of these studies.

In [5], using an automated method based on image processing, after normalizing the image, preprocessing methods were applied to enhance the image and prepare it for main processing. Subsequently, using edge detection techniques and edge following, candidate regions of interest were obtained. By applying appropriate conditions based on prior knowledge about the spinal cord and vertebrae, the desired regions were identified. In this study, an accuracy of 72% was achieved. Imianvand et al. (2012) presented a fuzzy clustering tool (FCM) to analyze different forms of multiple sclerosis (MS) and diagnose it. In this system, by classifying, verifying, and matching symptoms, patients were divided into two groups: a cluster of improved MS patients and those with primary progressive MS [7].

A fuzzy decision support system based on ontology was proposed by Esposito et al. (2011) for MS. The knowledge base in this system was collected from the medical knowledge of neurologists and biological data using the "thinking aloud" method. In this system, descriptive knowledge was represented through ontology modeling, and procedural knowledge was modeled using fuzzy logic in the form of "if-then" rules. The performance of this system was evaluated on 323 patients.

Fazel Zarandi et al. (2014) used a rule-based fuzzy system for MS diagnosis. Decision-making in these systems is based on the characteristics, signs, and symptoms of individuals. This system can serve as an advisor for neurologists or assist physicians in diagnosing the disease. Their proposed system consists of the following modules: 1. User interface, 2. working memory, 3. Knowledge base. The working memory displays a set of events related to MS [16].

The rule-based fuzzy expert system implemented by Bourghaniyan (2012) is designed for the diagnosis of neuromuscular diseases, including cerebral palsy, multiple sclerosis (MS), muscular dystrophy, and Parkinson's disease. Their proposed system is a rule-based expert system that is executed using JESS. This system utilizes a backward chaining inference engine. In this system, the user diagnoses the disease based on a list of questionnaires regarding the symptoms of patients and suggests possible treatments.

In [19], various algorithms such as GBM (Generalized Boosted Regression Model), GLMnet (Generalized Linear Model), k-nearest neighbors, multilayer perceptron neural networks, random forests (RF), and support vector machines were used for the diagnosis of MS. Among these, the random forest algorithm achieved the best result with an accuracy of 82%.

In the proposed method of the present research, the diagnosis of multiple sclerosis (MS) is addressed using neural networks. This research falls under applied research and is of a modeling type. The dataset has been prepared according to the previous section and will be used for simulating the MLP neural network and long short-term memory (LSTM) network. Support vector machines will also be used for comparison of results. Additionally, MATLAB software will be utilized for simulation in this research.

The steps of the upcoming research are as follows:

1. Study and complete understanding of multiple sclerosis, machine learning, and neural networks

2. Preparation of the required dataset

3. Providing an analytical model for the data and discovering patterns for diagnosing MS

4. Examination and evaluation of the extracted patterns

5. Analysis of the obtained results

The proposed algorithm in the present research is as follows:

1. Preparation of the dataset (multiple sclerosis disease)

2. Data preprocessing

3. Implementation of the neural network algorithm

4. Evaluation and comparison of results based on accuracy, precision, and recall metrics.

Initially, data preprocessing and normalization are performed, and then the feedforward multilayer neural network and the deep LSTM neural network are applied to the datasets. Additionally, a support vector machine with a Gaussian radial basis kernel is used to compare the results. The metrics considered for evaluating the performance of the proposed hybrid method in the present research include accuracy, sensitivity, and specificity.

TP is equal to the number of samples belonging to the class "Individuals without MS," and the proposed algorithm has predicted the class "Individuals without MS" for them.

FP is equal to the number of samples belonging to the class "Individuals without MS," but the proposed algorithm has predicted the class "Individuals with MS" for them.

TN is equal to the number of samples belonging to the class "Individuals with MS," and the proposed algorithm has predicted the class "Individuals with MS" for them.

FN is equal to the number of samples belonging to the class "Individuals with MS," but the proposed algorithm has predicted the class "Individuals without MS" for them.

Results

Multiple sclerosis (MS) is an inflammatory disease in which the myelin sheaths of nerve cells in the brain and spinal cord are damaged. This damage can disrupt the ability of parts of the nervous system that are responsible for communication and lead to a variety of physical symptoms. MS manifests in several forms, and new symptoms may occur either as relapsing (in a completely reversible manner) or over time (in an intermittent manner). It is possible that between relapses, signs of subsequent stages may continuously diminish; however, permanent neurological problems particularly occur with the progression of the disease. Although the exact cause of the disease is not clear, its primary mechanism involves damage caused by the body's immune system or dysfunction in the cells that produce myelin sheaths. Proposed reasons regarding these mechanisms include genetic factors and environmental factors such as infections. MS is usually diagnosed based on symptoms and medical test results. Multiple sclerosis is a progressive autoimmune disorder in which the protective coverings of nerve cells are damaged, leading to reduced function in the brain and spinal cord. Researchers know that MS involves nerve damage caused by inflammation, but the cause of the inflammation remains unknown. The symptoms of MS are variable and unpredictable. No two individuals with MS have exactly the same symptoms, and a person's symptoms can change or fluctuate over time. One person may experience only one or two symptoms of MS, while another person may exhibit a greater number of these signs.

Conclusion

An individual with multiple sclerosis (MS) exhibits all symptoms or neurological signs; the most common of these signs include issues with the autonomic nervous system, visual disturbances, motor problems, and sensory issues. Specific symptoms are identified through lesions in the nervous system and include numbness or tingling sensations, spasms, muscle weakness, involuntary reactions, muscle cramps or inability to move, coordination and balance difficulties, muscle incoordination, speech problems or dysphagia, visual issues (eye movement problems, reduced vision or double vision), feelings of fatigue, severe pain or chronic pain, and difficulties with urination and defecation. Cognitive difficulties and emotional problems such as depression or emotional lability are also common among individuals with MS.

This study examined definitions and previous research regarding the diagnosis of MS using machine learning and artificial intelligence methods. In this research, data from 600 patients with MS were utilized, followed by data preparation and preprocessing. Next, a Multi-Layer Perceptron (MLP) neural network and a Deep Learning Long Short-Term Memory (LSTM) neural network were applied to the preprocessed data.

• It is recommended that the relevant authorities in the Ministry of Health and Medical Education issue necessary circulars to all hospitals, healthcare centers, and physicians' offices to ensure that general patient information is recorded and stored in computerized systems. This is because the larger, more complete, and more accurate the collection of information at our disposal, the more optimal and ideal results we will achieve from the expert systems utilized.

• Utilizing other expert systems and applying them to the dataset used in this research, and comparing the results obtained with those from the current study.

• Combining neural networks with evolutionary algorithms for the diagnosis of multiple sclerosis.

• Applying the method used in this research to data from other diseases.

• Considering additional evaluation criteria beyond those considered in the current research, such as execution speed.

In this study, MATLAB software was used to simulate the proposed hybrid model, and metrics such as accuracy, sensitivity, and specificity were employed. By evaluating and analyzing the results, it was observed that the LSTM method performed better compared to the other methods in terms of the considered metrics.

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