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THE DEVELOPMENT OF AN ACCURATE AND EFFECTIVE CONVOLUTIONAL NEURAL NETWORK TO DIAGNOSE PARKINSON'S DISEASE

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ABSTRACT

In 2022, a Parkinson's Foundation-based study reported that about 90,000 people are diagnosed with Parkinson's disease in the US each year (Parkinson's Foundation, 2018). Around 7 to 10 million individuals worldwide are currently living with Parkinson's, making it the second most common neurodegenerative disorder in the world (Parkinson's News Today, 2023). Parkinson's disease predominantly affects the neurons that produce dopamines in two areas of the brain called the *basal ganglia* and the *substantia nigra* (Mayfield Clinic, 2018). However, there is no cure for this chronic disease nor is it easy to diagnose, especially in its early stages (Parkinson's Foundation, 2018). Because symptoms often appear only 1-2 years after the disease, people are often left undiagnosed during this period (Mayo Clinic, 2015). With this being said, reliable methods of diagnosis are vital to individuals with Parkinson's. As a solution, a convolutional neural network algorithm was developed to accurately and effectively diagnose Parkinson's in patients using audio and biometric data. The capabilities of the convolutional neural network algorithm allowed for 2 results: either the patient has Parkinson's or the patient doesn't have Parkinson's. Our algorithm showed an accuracy of 0.7528.

Keywords: Parkinson's Disease, CNN, Machine learning, Medical AI, Diagnosis

Introduction

Parkinson's disease, as previously stated, is a neurodegenerative ailment that damages nerve cells in two major parts of the brain: the *basal ganglia* and the *substantia nigra*. Dopamine is produced by nerve cells in certain parts of the brain and is essential in the planning and regulation of bodily movement. Tremors, slowness of movement, stiffness, and balance issues develop as dopamine-producing nerve cells decline. The *basal ganglia* is in charge of ensuring

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that any movement occurs in a fluid and seamless manner. When dopamine receptors are not correctly activated, portions of the *basal ganglia* are either over-stimulated or under-stimulated, resulting in a loss of mobility and stiffness (Mayfield Clinic, 2018). However, the exact cause of the decline of the neurons is still unknown. The symptoms of Parkinson's usually worsen over a long period of time.

Symptoms frequently appear on one side of the body, or even in a single limb on one side of the body. The disease gradually affects both sides as it progresses, although, the symptoms may be worse on one side than the other. Parkinson's has 4 broad categories of symptoms: tremors, muscle stiffness, slowness of movement, and impaired balance and coordination. Other common symptoms include emotional/mental changes, difficulty speaking, urinary problems or constipation, and skin problems (National Institute of Health, 2022). In terms of speech, Parkinson's affects the larynx, throat, respiratory muscles, roof of the mouth, and more. Some of the speech difficulty symptoms include a softened voice, a monotone voice, a hoarse or strained quality of voice, and a slurring ofspeech (Cleveland Clinic, 2020).

Currently, there are no blood or laboratory tests to diagnose Parkinson's caused non- genetically (National Institute of Health, 2022). However, in 2011, the US Food and Drug Administration gave the DaTscan imaging scan its approval. Using this method, medical professionals may view in-depth images of the dopamine system in the brain. An MRI-like device called a single- photon emission computed tomography (SPECT) scanner and a little quantity of radioactive medication are used in a DaTscan.The medication attaches to brain dopamine transmitters, indicating the location of dopaminergic neurons. Parkinson's, as said before, is caused by a lack of dopamine, which is produced in the brain by dopaminergic neurons. The results of a DaTscan can assist your doctor to confirm a diagnosis or rule out a Parkinson's mimic, but they cannot prove that you have Parkinson's (Hopkins Medicine, 2021). Parkinson's disease can also be determined by your medical history, an analysis of your signs and symptoms, and a neurological and physical examination by a doctor specializing in nervous system diseases (neurologist) (Mayo Clinic, 2015). Parkinson's disease (PD) is clinically diagnosed when the recognizable motor symptoms of bradykinesia, stiffness, postural instability, and resting tremor are present (Lehericy et al., 2017). Lastly, a specific response to a Parkinson's treatment may occasionally reveal the diagnosis of Parkinson's. The doctor may give a medicine designed for Parkinson's disease to provide further information if a patient's symptoms and neurologic examination are just indicative of the condition or if the diagnosis is otherwise uncertain. When treating Parkinson's disease, medicine usually has a favorable, predictable response in cases of idiopathic Parkinson's; but, in other associated Parkinsonian syndromes, this response may be weak or nonexistent (American Parkinson's Disease Association, n.d.).

Although the methods above paired with manual analysis are highly useful in theory, there is a

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probability that the diagnosis will be off. Depending on the clinician's experience, the misdiagnosis rate of Parkinson’s might be as high as 20% (Hess et al., 2016). As a solution to this problem, various artificial intelligence models that aid in the diagnosis and monitoring of Parkinson’s have been employed, such as those by MIT. Researchers at MIT have created an artificial intelligence (AI) model that uses nocturnal breathing patterns, which take place when a patient is asleep, to identify the existence and severity of Parkinson's disease. Overall, the model was highly effective in detecting the presence and severity of Parkinson's as well as accurately following the progression of Parkinson's over time (Kennedy, 2022). The benefits of using machine learning technology include diagnosing illnesses early, enhancing therapies, and finding hidden or complicated patterns in diagnostic data (GAO, 2022).

One of the most reliable, convenient, and cost-effective sample-collecting techniques was used for this project's training and input data collection: audio and biometric data. As a result, the method that was developed is more efficient and affordable for the diagnosis of Parkinson's disease. Our solution uses the Python programming language, Numpy library, XGBoost open-source software library, Keras open-source software library, Panda’s data frame, and TensorFlow. The entire program was written within the Google Colaboratory data science notebook.

Procedures

In this research, a convolutional neural network technique was used because of its excellent processing efficiency and accuracy (Dertat, 2017). The TensorFlow machine learning framework, which is coupled with the Keras deep learning library for quick numerical calculation, was used to apply the technique. The solution utilized statistics from a research paper published on ResearchGatewere used for training, validation, and testing of the model. With over 1400 recordings utilized, the model quickly utilized varying possibilities shown in patients; each data point helped guide the machine in a more definitive conclusion on emerging signs for patients with Parkinsons.

Using the given training data, which had varying clips of audio recordings identified in each patient, the model is now ready to start sorting each data point thoroughly. It is able to efficiently accomplish this through the use of speech recognition patterns identified in each patient given to the machine in sorted categories of small snippets of voice recordings. This then allows it to further identify a possible patient due to emerging patterns in each data point, quickly becoming more and more accurate with each new data point.

Training and Validating the model

The ReLU activation function was employed due to its advantages in backpropagation and in addressing the problem of gradient descent. The sigmoid activation function was also utilized to

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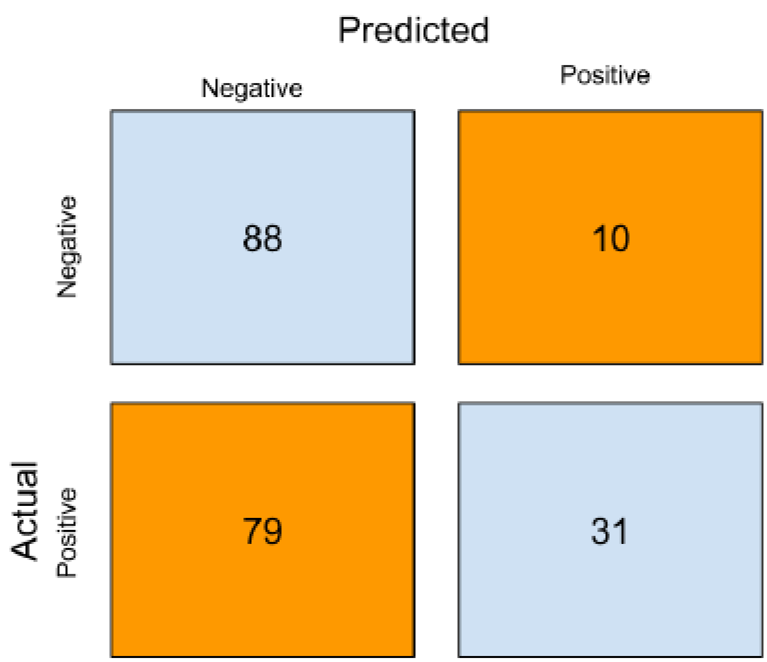
enable binary classification, i.e., whether the subject had Parkinson's disease or not. The Adam optimizer, which combines RMSprop and Momentum, was used to optimize gradient descent and shorten training time. The binary cross-entropy loss function was used to assess the model and the accuracy of its predictions.

Testing the model

The first iteration of the model had 50 epochs and yielded an accuracy of 0.6827, a loss of 0.5710, and the validation set had an accuracy of 0.5962. The second iteration of the model had 100 epochs and yielded an accuracy of 0.7548, a loss of 0.4664, and the validation set had an accuracy of0.6202.

Metrics

The "loss" variable, which is part of each epoch output line, is a feature of the Keras library that was used to evaluate errors. Binary cross entropy was employed to calculate the "loss" variable, which had a scalar value between 0 and 1. The overall accuracy for the model was determined to be0.7548. A confusion matrix is depicted below.



Shape(hidden layers): [32,32,32,1]

Batch Size: 16

Epochs: 100

Training Size: 1040 data points

Testing Size: 169 data points

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Conclusion

Using our convolutional neural network algorithm, the model identified both condition categories and exhibited a final accuracy of 0.7548 and a loss of 0.4664. When compared to currently available solutions like DaTscan and physical inspection of Parkinson's symptoms, our machine learning model offers neurologists a more quick and affordable method for arriving at a diagnosis.The proposed method also allows a larger part of the world's population who do not have access to advanced technology to obtain a reliable diagnosis.

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