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A Survey on Identification of Neurological Diseases with the Handwritten Characters

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Abstract: Brain controls the writing process. Adult brain contains about 100 billion nerve cells or neurons. They are the building blocks of the nervous system which includes the brain and the spinal cord. They don't reproduce or replace themselves, so when they become damaged or die, they cannot be replaced by the body. Neurodegeneration is the progressive loss of function of the neurons including the death of neurons. Patients suffering from neurological diseases will experience tremor, dysgraphia and micrographia. It is a medical condition that arises because of damage to basal ganglia in the brain, the area that controls fine motor movements. These neurological problems affect handwriting. The idea of this paper is to study the various algorithms that has been used to identify Parkinson disease.

Keyword: Neuron, Synapse, Neurotransmitter, Neurodegeneration, Dopamine, Substantia nigra.

1. INTRODUCTION

Diagnosis of diseases based on various tests is a challenging task. It is even more challenging when there is an enormous increase in number of patients. It leads to stress and workload pressure. This has given rise to clinical decision support system that helps the doctors in clinical decision making process. The idea is to detect neurological diseases using machine learning algorithm.

The human brain is hugely interconnected but three major components can be identified: the cerebrum (forebrain), the cerebellum and the brain stem (medulla). The cerebrum consisting of 75% of the brain by volume and 85% by weight is divided into two distinct hemispheres, the left and right hemisphere. The brain's left hemisphere controls writing.

Adult brain contains about 100 billion nerve cells or neurons. Neurons are the building blocks of the nervous system which includes the brain and the spinal cord. Neurons don't reproduce or replace themselves, so when they become damaged or die, they cannot be replaced by the body. Signals that form memories and thoughts move through an individual nerve cell as a tiny electrical charge. Nerve cells connect to one another at synapses.

When a charge reaches a synapse, it may trigger release of tiny bursts of chemicals called neurotransmitters. The neurotransmitters travel across the synapse, carry signals to other cells.

Neurodegeneration is the progressive loss of function of the neurons including the death of neurons. The neurodegenerative disease disrupts both the way the electrical charges travel within cells and the activity of neurotransmitters. It leads to cell death and tissue loss throughout the body. Over time, the brain shrinks dramatically. Individuals lose their ability to communicate, care for themselves and recognize their family and loved ones.

2. NEURODEGENERATIVE DISEASE

Parkinson's disease is second largest neurological disorder that targets brain cells that control movement. It targets neurons that produce an important chemical called dopamine. Dopamine is a chemical messenger that transmits signals within the brain. Normally, dopamine operates in a delicate balance with other neurotransmitters to help coordinate the millions of nerve and muscle cells involved in movement. Because Parkinson's patients have a loss of dopamine-producing cells in the brain, the coordination among nerve and muscle cells is disrupted.

A person with Parkinson's has abnormally low dopamine levels. Dopamine-generating cells, known as dopaminergic neurons (types of nerve cells) in the substantia nigra part of the brain have died. Dopamine is involved in the sending of messages to the part of the brain that controls coordination and movement.

Though this paper deals with parkinsons disease, other neurodegenerative diseases are also discussed here. Alzheimer disease is ranked the top most neurodegenerative disease. There is progressive brain cell death over a course of time. Tremor is an unintentional, rhythmic muscle movement involving to and fro movements of one or more parts of the body. It makes them harder to do day to day task and goal oriented task such as handwriting and speaking. Dystonia is a disorder involving slow repetitive movements or abnormal patterns. Individuals with dystonia experience worsening of handwriting after writing several lines. Dys means difficulty and graphia means writing. Dysgraphia is "Disorder of written expression" and writing skills are below those expected given the person's age, intelligence and education. Micrographia is a term where the handwriting becomes progressively becomes smaller and harder to read. It is a medical condition that arises because of damage to basal ganglia in the brain, the area that controls fine motor movements. This is a common symptom in individuals with parkinsons disease. These neurological problems affect handwriting.

3. DETECTING NEUROLOGICAL DISEASES THROUGH HANDWRITING

Neurological diseases can be identified using the handwriting. The handwritten characters of the individuals are scanned, preprocessed, segmented, features are identified and classified as patients suffering from neurological diseases or not.

4. EXISTING SYSTEM

In Evaluation Of Handwriting Kinematics And Pressure For Differential Diagnosis Of Parkinsons Disease[1], Kinematic features such as drawing Archimedean spiral, repetitively writing orthographically simple syllables, words and writing of a sentence and Pressure feature like pressure exerted on the writing surface is used for differential diagnosis of PD. Classifiers like K-nearest neighbors (K-NN), ensemble AdaBoost Classifier, support vector machine (SVM) are used. SVM is best performing model with classification accuracy of pacc = 81.3 % (sensitivity psen = 87.4 and specificity of pspe = 80.9%). Pressure features yielded pacc = 82.5% and kinematic features yielded pacc = 75.4%. The advantage of this method is that it has considered kinematic and pressure features. But the drawback of this method is that SVM classifier has given a classification accuracy of 81.3%.

In Analysis Of In-Air Movement In Handwriting: A Novel Marker For Parkinson's Disease[2], the handwriting of a text consists not only the on-surface movements of the hand, but also the in-air trajectories performed when the hand moves in the air from one stroke to the next. Here both in-air and on-surface kinematic variables are identified. Feature selection algorithms and support vector machine learning methods is applied and the in-air/on-surface hand movements led to accurate classifications in 84% and 78% of subjects, respectively. Combining both modalities improved the accuracy by another 1% over the evaluation of in-air features alone and provided medically relevant diagnosis with 85.61% prediction accuracy. The advantage of this method is the on-surface movement and in-air trajectories were considered but the drawback is that the SVM method gave a classification accuracy of 78%. However combining both feature selection algorithm and SVM gave 85.61% prediction accuracy.

In Decision Support Framework For Parkinsons Disease Based On Novel Handwriting Markers [3], in addition to conventional kinematic and spatio temporal handwriting measures, novel handwriting measures based on entropy, signal energy and empirical mode decomposition of handwriting signals were calculated. Selected features fed to SVM classifier with radial Gaussian kernel for diagnosis. Accuracy was as high as 88.13% with highest value of sensitivity = 89.47% and specificity = 91.89%. The advantage of this method is entropy, signal energy etc gave an increase in accuracy but the drawback is that it contains only selected features.

In Handwriting as an objective tool for Parkinson's disease diagnosis [4], Mean pressure and mean velocity was measured for the entire task and the spatial and temporal characteristics were measured for each stroke. Kappa value was calculated. Significant groups effects were identified. Based on the discriminant function, 97.5 % of participants were correctly classified (100 % of the controls and 95 % of PD patients). The advantage of this method is the significant groups were easily identified and discriminant function gave a classification accuracy of 95% in PD patients.

In Handwriting Analysis For Diagnosis And Prognosis Of Parkinsons Disease[5], Receiving operating characteristics (ROC) analysis and Relative number of loop extremes, Impulse correlation coefficient, Approximation entropy, Mutiscale entropy, Power rate coefficient is considered. ROC curve of AUC = 0.933, Impulse correlation coefficient = 0.86, Approximation entropy = 0.905, Mutiscale entropy = 0.859, Power rate coefficient = 0.84. The advantage of this method is combining all features gave nice ROC with good AUC of 0.963.

In Diagnosing Parkinson by using Artificial Neural Networks and Support Vector Machines[6], voice recording of the individuals instead of handwriting is considered. System with ANN and SVM is built. The accuracy of the ANN and SVM were very good. They showed a high degree of certainty, above 90%. Furthermore, some of the parameters reached very high accuracy such as "Sensitivity" and "Negative predictive value" with 99.32% and 97.06% respectively. The advantage of this method is the classification accuracy shows high value. But the limitation is the voice recording of the individuals were considered rather than handwriting.

In Diagnosis of Parkinson's Disease using Fuzzy C-Means Clustering and Pattern Recognition[7], voice samples of the individuals is considered. application of fuzzy c-means classification and pattern recognition to a medical dataset concerning PD with the aim of automatically classify patients in PD or non-PD. Success % is 68%. The advantage of this method is the latest techniques have been applied but the drawbacks of this method is voice is considered and success is 68.04%.

In Classification of Parkinson's Disease using MRI Images[8], GLCM and Multilayer perceptron neural network is used for diagnosis of Parkinson disease. When statistical features, geometrical features and Gabor texture features are added successively into the feature vector the classification gives the correct rates of 79.82% and 79.67%. Then the Sequential Backward Selection (SBS) and the Sequential Forward Selection (SFS) are used, respectively, to minimize the best feature subset. Comparatively, the feature subset obtained by SFS gives the

highest classification rate of 96.58%. The advantage of this method the classification rate is high using GLCM method but this method requires MRI images.

Other papers established relationship between handwriting and neurological diseases. In Handwriting Characterization Of Neurodegenerative Disease[9], script is scanned, binarized and Filtered. Features are extracted and classification measures SD using height, width, aspect ratio, and stroke to area ratio. Online handwriting measures duration, absolute peak vertical velocity (PVV) and number of vertical acceleration peak (APK). Algorithm used in perturbation method (Thein M. Ha and Horst Bunde) is used to calculate geometric transformation like rotation, shrink, perspective view and slant. Segmentation algorithm (Elena Kalcheva) – cc and bb cause symbol to be identified and separated based on height and width of stroke. Normalized jerk averaged per stroke = $(0.5 \times (\sum \text{jerk}(t))^2 \times \text{duration} / \text{length}^2)^{1/2}$ is calculated. If $\text{Jerk} > \text{threshold} \Rightarrow$ neurological disease. Thus the relationship is established between handwriting and parkinsons disease.

In The Effects Of Dual Tasking On Handwriting In Patients With Parkinsons Disease[10], the effect of secondary cognitive task on performance of handwriting in PD patients, dual task effect = $(A/B) \times 100$ is calculated where $A = (\text{Dual task performance} - \text{Single task performance})$ and $B = \text{Single task performance}$. SOS score is calculated based on fluency, regularity and space. For the given data, following are calculated - Outlier values ($+2$ SD), Mann Whitney U test, Chi square test, Amplitude and velocity is analysed using 2×2 repeated analysis of variance (ANOVA), Tukey honest significance test, Wilcoxon signed rank test, Spearman's rank correlation, Purdue Pegboard test. Patients with PD wrote slower than healthy controls in both single and dual tasking.

In Segmentation And Analysis Of Handwritten Scripts From Patients With Neurological Disease[11], Automatic segmentation and analysis of handwritten scripts of both healthy and ND patients, Following are calculated: (A) *Segmentation* – Project Profile technique using connected component and bounding boxes, (B) *Straight line technique using least square technique*, (C) *Feature extraction*, (D) *Aspect ratio = width/height*, (E) *Stroke to area ratio = $n/(w \times h)$* , (F) *Stroke frequency = N/Length* , (G) *Slope angle = $\arctan(b)$* , (H) *Baseline variability $f_i = si/\text{length}_i$* , (I) *2 side t test for significance of baseline variability*, (J) *Stroke frequency*, (K) *Average width*. It is concluded that tremor influences writing control of ND patients and analysis of handwriting can be used as a reliable tool for assessment and evaluation of ND.

5. PROPOSED SYSTEM

The Parkinson's Disease Handwriting Database consists of multiple handwriting samples from parkinsonian patients and healthy individuals. Handwriting is acquired and saved as image. This image is converted to gray scale, edges are detected and preprocessed. Segmentation is done on the preprocessed image. Then the features are extracted and classification is applied. Following steps are carried out in MATLAB.

- A. Image acquisition
- B. Pre-processing of the uploaded image
- C. Segmentation
- D. Features Extraction from processed image
- E. Classification and Recognition

Fuzzy c-means referred in Diagnosis of Parkinson's Disease using Fuzzy C-Means Clustering and Pattern Recognition[7] is to be applied along with GLCM referred in Classification of Parkinson's Disease using MRI Images[8]. Finally ANFIS classifier is to be applied and the proposed algorithm needs to be compared with existing algorithms.

6. CONCLUSION

The patients suffering from neurological diseases can be identified using their handwriting. Thus it reduces the burden of the doctors when the volume of data increases. This can aid the doctors in decision making and help in early identification of disease.

7. FUTURE ENHANCEMENTS

Efficiency of the proposed algorithm has to be calculated and compared to the existing algorithms. Variations in the algorithm can be done by adding filters to see if the efficiency is better than other algorithms including the proposed algorithm. In future this algorithm can be used to detect neurological disease through speech and smell also.

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