

Handwriting Characterization of Neurodegenerative diseases

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Abstract-There is no definite relationship between handwriting patterns of a patient suffering from a neurodegenerative disease and the disease itself. It is a known fact that handwriting of a patient can depict the intensity of this disease and can be taken as a symptom or detection tool, yet no standard theory or tool exists. This paper tries to find that definite relation between handwriting and the associated diseases.

1. INTRODUCTION

Neuro degeneration is a process in which the neurons lose their structure and functionality; this ultimately leads to the death of neurons. Neurons (or widely known as nerve cells) are mainly responsible for accepting information, synthesising information and passing appropriate signals, based on the information sent, to other neurons or glands. All the voluntary movements of the body are hence by controlled by these cells. Any deformity in the neuron cells may cause severe diseases like Parkinson's, Alzheimer's, Lewy Body Dementia, Ataxia and Huntington's (Movement Disorders).

This paper's objective is to understand a perfect relation between the jerks caused in handwriting while a person suffers from neuro degenerative diseases. Since in off line handwriting many algorithms can be used to identify the symbols in the written script it can be inferred that the number of stages of algorithm combination used is exponentially proportional to the jerks experienced by the subject. Various methodologies like open loop concept (especially with characters like "llll"),Micrographia, previous papers on handwriting recognition etc were analysed and implemented for the understanding the handwriting terminology.

Several methods have been proposed over the years to measure the deviations, from intramuscular nodes to electronic pens to various instrumentation techniques. Of late on line handwriting recognition has been heavily dependent on graphic tablets which verify the pixel formation from the subjects' writing. Though off line has seen breakthrough in the recent years with better instrumentation, it has still a long way to go compared to on line techniques. One possibility of a better off line handwriting recognition method is to use handwriting recognition algorithms in the handwriting samples after scanning them.

2. RELATIONSHIP BETWEEN HANDWRITING AND DISEASES

In general all neurodegenerative diseases have similar set of symptoms like distortion in handwriting, involuntary motions in organs, loss of vision etc. These diseases are

generally caused due to mutation in genes which leads to expansion of CAG trinucleotide and polyQ tract. Although there are other cells and factors which are responsible for this disease, but the most common one is CAG expansion. This expansion produces irregular functionality of organs in body and eventually contributes towards deterioration of handwriting. Hence, it can be said that the pattern of handwriting can play an important role in predetermining these form of diseases. Although it cannot be the sole parameter onto which the existence of this maladies can be determined, but it can act as a contributing factor. Huntington's Disease, Osteoarthritis, Rheumatoid Arthritis, Keratoconus, Parkinson's Disease, Cancer and Atherosclerosis are some of the examples of neurodegenerative diseases.

3. METHODS TO DETECT

There are basically two methods to detect handwriting, offline and online.

Online handwriting recognition is mostly implemented using digital pens and tablets. The digital pen has sensors that capture pressure and force exerted by the patient while writing. However, for the patient the experience would be same as writing with a ball pen. This method is called online as no scanning or any other form of conversion is required to load the samples in the computer.

On the other hand, offline handwriting recognition is a different methodology. In this, the samples are scanned and loaded onto a computer where various softwares are used to analyse the samples.

As online handwriting has mostly made use of instruments to detect any jerks, offline recognition is generally more difficult. Jerks in handwriting are mainly deviations in the standard movement of the stroke. These strokes are generally filtered using some type of algorithm. It can be thus inferred that the multiple stages algorithms [6] are used indicates an increased possibility of neurodegenerative disease affecting the subjects handwriting.

Diseases and previous observations

Since handwriting is the task which requires maximum level of muscular control any signs of deviations in the handwriting can be a possible indication of Neuro degenerative disease. Although other motor skill tests like reaction time, balance, etc are also conducted handwriting analysis is a recent approach which could help in successful diagnosis.

Several diseases like Parkinson's and Alzheimer's are already being diagnosed by changes in motor skills. Many studies are being conducted on them in addition to other

degenerative diseases like Apraxia, Aboulia, etc. Also in addition to diagnosis the long term effects of the medicines used to treat these diseases is also studied to find a correlation between handwriting and EPS (extra pyramidal side effects.)

A common feature of neurodegenerative diseases is to have difficulty in routine activities due to lack of overall control of movement. More specifically, patients have difficulty maintaining the scale of movements and have reduced amplitude of movement; also known as hypokinesia. These difficulties with scaling and controlling the amplitude of movement cause patients with PD to have difficulty with complex, sequential movements. This helps to explain why micrographia is a common sign and symptom of the disease.

An interesting way of detecting handwriting through pattern recognition is neocognitron. The neocognitron is a hierarchical multilayered neural network proposed by Professor Kunihiko Fukushima. The neocognitron is a natural extension of these cascading models. In the neocognitron, which consists of multiple types of cells the most important of which are called S-cells and C-cells, the local features are extracted by S-cells, and these features' deformation, such as local shifts, are tolerated by C-cells. Local features in the input are integrated gradually and classifying in the higher layers. The idea of local feature integration is in several other models such as LeNet and SIFT model.

4. JERKS AND HAND WRITING

Jerks can be seen as perturbations in handwriting. Their perturbation models aim at representing deviations in handwriting from what are called 'standard patterns' [3]. Thus the number of transformations made on the sample handwriting to get a close match with the standard pattern is an indicator of the level of handwriting control.

Since offline handwriting is a combination of several transformations and rotations of lines in two dimensions as compared to the one dimensional view of on line handwriting, an algorithm for determining the probability that a symbol is mostly a recognised letter or numeral. The repeated application of these algorithms would enhance the symbol recognition effort.

Some subjects develop writing styles requiring greater number of strokes per letter compared to others; however it is assumed it will not affect the group differences due to the moderately large sample subject size. Hence, it is possible to leave the consideration of different handwriting styles like print or cursive for jerks in the script.

5. ALGORITHMS USED

Since most handwritten scripts involve the movement of the pen from top to down so as to create a vertical stroke, deviations in the stroke pattern are called jerks. Considering that the script is written in a linear pattern, the algorithm used is required to analyse each symbol or character by dividing the script into several segments using vertical separation.

First the script is scanned in the case of off line handwritten scripts and then it is binarized and filtered. Then specific algorithms can be utilised.

After the delimiting of symbols the feature extraction and classification can be performed by a sophisticated algorithm which is used to measure the standard deviation in the script using various parameters like height, width, aspect ratio, stroke to area ratio and in the case of online handwritten samples we can capture duration, absolute peak vertical velocity (PVV) and number of vertical acceleration peaks (APK).

All the algorithms suggested are used for the purpose of smoothening and removing deviations in the handwritten script rather than focusing on identification of the symbol. As the main aim is to find the lack of control in the subject's writing motion.

1. Here we reference the algorithm used in, a perturbation method given by Thein M. ha and Horst Bunke is used." A parameterization can be based on geometric transformations like rotation, shrink, perspective view and slant." This would cause the first stage of detection as in the case of several neurological diseases, the script would not have the same base line.

2. After the first round of geometric transformations done to change the symbol, another feature extraction algorithm can be applied to perform the second round of symbol recognition. After the possible transformations are done to the script, we refer to the algorithm for segmentation suggested by Elena Kalcheva, Georgi Gluhchev [5]. The use of CCs (Connected components) and BBs (Bounding boxes) causes the symbols in the script to be identified and separated in boxes based on the height and width of the stroke.

The text line separator is used to determine the gravity of the symbols in the script and thus find the separation between each symbol in case of connected writing style. Then the parameters of the script can be taken as input for Feature Extraction algorithm to get the standard deviation of the script symbols.

3. In the case of online handwriting samples for Quantifying EPS in Patients Treated with Atypical Antipsychotics) the duration which the digital pen touches the digital pad to make a stroke can also be measured which would help us to calculate the normalized jerk averaged per stroke [4]. It was calculated using the following formula

$$(0.5 \times \Sigma (\text{jerk}(t))^2 \times \text{duration}^5 / \text{length}^2)^{1/2}$$

Where jerk(t) is the jerk in pen for single symbol and it is taken as a cumulative value. duration is time taken by pen to leave the pad after writing and length is length of stroke. If the average normalized jerk for the script is greater than a threshold value then it can be inferred that there is a chance of neurological disease affecting motor skills.

If the threshold of the jerks is beyond the threshold of handwritten symbols for subjects without neurological disorders then it can be assumed that the subject may be suffering from a neurological disease which causes muscular tremors.

6. CONCLUSIONS

From this paper, we have tried to establish an idea that enounces the relationship between handwriting and neurodegenerative diseases. The motion abnormalities reflect the patient's inability to control hand and body movements. Based on this fact and previous experiments, we have tried to portray jerks and pattern of handwriting as a symptom. Moreover, various existing algorithms are also analysed and examined in order to identify if they fit in the current theory. The sole aim of this paper is to interpret handwriting as a detecting tool for neurodegenerative diseases.

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