Effects of Neurodegenerative Diseases on Handwriting

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Abstract—**Exponential death of neurons cause loss of motor control which eventually leads to movement and memory disorder. The former is known as ataxias and the latter is known as dementias. Such disorders leads to clinical conditions broadly called as neurodegenerative diseases. These diseases are incurable but a keen observation and analysis of habits and behavior can result in early diagnosis of neurodegenerative diseases. This paper describes various such traits of handwriting which can be used as markers in any automated system for early diagnosis of such diseases . If diagnosed at an early age, effects of such diseases can be minimized and delayed further.**

IndexTerms— **Neurodegenerative diseases, motor control.**
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I. Introduction

Neurodegenerative disease is a broad term used for variety of conditions which significantly affect the neurons in the human brain. Neurons are the atomic units of the nervous system which are used to transfer signals in form of electrical pulses to all the organs in a body. Motor neurons control intentional muscle activity for instance writing and take messages from nerve cells in the brain to the muscles. Neurons do not replicate themselves. Thus, when these neurons die due to some clinical disorder they cannot be replaced or replicated which causes eventual loss of communication between brain and sense organs. Examples of neurodegenerative diseases include Parkinson's, Alzheimer's, and Huntington's disease. These diseases are not curable and eventually causes degeneration and death of nerve cells, due to which movement disorder known as ataxias or memory disorder known as dementias are caused.

Some of the common Neurodegenerative diseases are Alzheimer's disease ,Parkinson's disease , Prion disease, Motor neuron diseases (MND), Huntington's disease (HD), Spinocerebellar ataxia (SCA), Spinal muscular atrophy (SMA). Neurodegenerative diseases (NDD) have an extreme effect on the nervous system which includes muscles, the nerve-muscle junction, nerves in the limbs, and motor nerve cells in the spinal cord etc. Nerve cells generates an electrical pulse and sends a messages that manage the muscles so as to allow movements of the body parts for various day to day tasks, including handwriting. Died or damaged neurons cannot appropriately control muscles.

Handwriting is one of the most noteworthy behaviors which are affected by such diseases. Handwriting is a result of a complex network composed by cognitive, kinesthetic, and perceptual-motor abilities. In addition to these, visual and kinesthetic perception, motor planning, eye-hand coordination, visual-motor integration, dexterity, and manual skills are involved. Considerable changes in the handwriting pattern are the significant feature of Alzheimer Disease (AD) as well as Parkinson Disease (PD). Learning and performing handwriting requires the interactions of multiple brain areas which includes cerebral cortex, basal ganglia and cerebellum. There are various features of the writing process that are more vulnerable than other and may register diagnostic signs. Handwriting analysis within this field of application is also encouraged by the fact that the Minnesota Handwriting Assessment (MHA) is used to identify students (6-8 years old) with difficulties related to autism. The test is also used to evaluate treatment effectiveness over time. It inspects the legibility, handwriting speed, form, alignment, size and spacing.

The patients of alzheimer's disease are observed to repeat some syllable and forgot others. Which eventually leads to distorted word forming and distinguished writing pattern. Such disturbances are known as lexicosemantic disturbances. It is a type of dementia that causes problems with memory, thinking and behavior. Disorders in handwriting abilities starts before AD can be diagnosed clinically, and become more significant with time. Due to this disease, the patient has difficulty in recalling the text he or she intended to write and remembering letters to form signature. Changes in handwriting resulting from AD are forgetting letters within the text, unnecessary repetition of letters and unreasonable connection lines between words.
On the other hand Parkinsson's disease, progressive deterioration of motor function is observed. Since irregular handwriting is a well recognized feature of Parkinson's disease with micrographia being characteristic, handwriting analysis can prove to be very important criteria for the diagnosis. Handwriting anomalies may appear at the early stages of the disease and thus may be one of the first signs of impending PD.
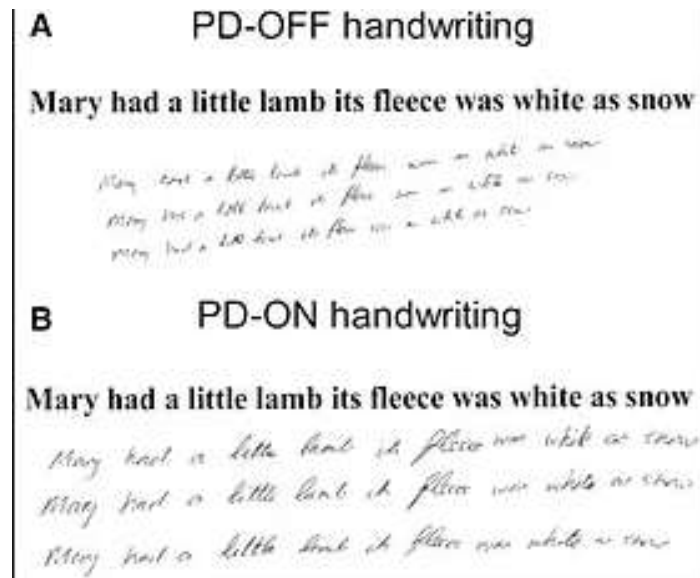
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Fig.1 A sample writing of Parkinsson's Disease patient and normal person. (Courtesy-Ling, H., Massey, L. A., Lees, A. J., Brown, P., & Day, B. L. (2012). Hypokinesia without decrement distinguishes progressive supranuclear palsy from Parkinson's disease. Brain, 135(4), 1141–1153. http://doi.org/10.1093/brain/aws038)

II. Methodology

As discussed in the Introduction, handwriting is a process that involves various complex communication processes in nervous system. It includes several cognitive abilities too. Due to this, handwriting analysis can be used as a powerful tool for early diagnoses for NGD [14, 23]. All the diseases have certain different effects on memory and motor control, thus creating different distortion in handwriting patterns. [8, 25, 33]. Various neural activities can be recorded for an effective study of brain areas related to motor learning. In the process of handwriting it is observed that two different parts of brain are involved. The learning of motor sequences by two distinct neural systems, consisting of cortex-basal ganglia and cortex-cerebellum loop circuits [12, 6]. A neural model of cortico-cerebellar interactions during attentive imitation and predictive learning of sequential handwriting movements, suggests how cortical mechanisms interact with predictive cerebellar learning during movement imitation [5]. A recurrent neural network actor-critic model of the basal ganglia and a feed-forward correlationbased learning model of the cerebellum was proposed suggesting that basal ganglia and cerebellar learning systems work in parallel and interact with each other. Still, these works did not provide computational models to test the validity of the neural schemes. To develop an effective and automated systems for the early detection and monitoring of NGD by Handwriting analysis, defining effective features plays a significant role.

Some special handwriting characteristics of the person's who are suffereing from neurodegenerative diseases are as mentioned below-

- **Writing speed-** when compared to the normal people, people suffering from such disorders are slower while writing. Due to continuous damage or death of neurons working of brain becomes slower. The cognitive power of a person also declines with the progress of disease. Which eventually leads to decreased writing speed.
  Speed of writing can easily be recorded by using electric pen and sensing tablets or digitizing tablets.

- **Jagged lines-** such lines are very significant feature of handwriting of those people who suffers from NGD. Since NGD effects the motor control mechanism of brain, it hampers normal hand movement too. Due to which shaky hands are always observed which directly effects the handwriting.
  Edge detection techniques can prove very helpful in identifying jagged lines in a particular writing specimen.

- **Micrographia-** It is one of the most significant characteristic of handwriting of NGD patients. While writing a long sentence considerable decrease in font size was registered usually. It also differs while writing in ruled or unruled papers as well.

- **Increased Movement time-** the reaction time of brain is increased, due to which all movements become slower.

- **Aspect ratio-** it has been observed that for each word there is significant change in height to width ratio. Since, the words are elongated and size of alphabets is decreased, significant changes in aspect ratio is recorded.

On the basis of above characteristics various feature sets can be designed for diagnosis of NGDs on the basis of handwriting. Any state of art classifiers can be used for classification purposes like SVM, radial basis function network, feed forward networks etc.

III. Future Aspect

Regarding early diagnosis of NGDs, some automated systems have been proposed. Still it has been observed that the efficiency of the systems can further be improved by paying attention to following problems-

First problem is lack of well identified ad designed datasets [30]. Design of database must be done on the basis of following significant features-

- Cardinality – The dataset used must not be very less or very large because it may lead to under fitting or over fitting of the specimen. In recent studies a considerable cardinality was fixed between 50-60 specimen per person[16].

- Acquisition tool and protocol: Data can be acquired online or offline. In an online data acquisition method the current state of a patient can be recorded instantaneously. The protocol used must be uniform for data collection as well as for current data acquiring. So as to maintain uniformity among the data.

- Cognitive model- NGDs do not involve only functional and behavioural changes but also result in progressive cognitive decay. The acquisition protocol should take into account, to some extent.

- Number and periodicity of sessions- So as to identify disease at various stages, a set of different users is needed. At the same time in order to have the possibility to understand the evolution of the disease over time, the same patient must be enrolled into the system in a periodic way, or when some specific event is occurred.

The second problem is the classification problem. Simple pattern recognition can work for such approaches but at the same time medical knowledge must also be incorporated. The medical knowledge of the evolution of the disease cannot be ignored. If an automatic system is able to diagnose a disease in it s mature state it is of no use in application world. It must be able to identify the disease in its early stage. Thus it is necessary to identify different stages and evolution of disease. Tracking the evolution and to identify signs of worsening is a must. Till date NGDs are not curable, but an early diagnosis of such diseases can slower the rate of damage and even delay it to some extent. Research on handwriting and neuro-muscular diseases is not expected to replace standard techniques, but to strengthen them by allowing an earlier diagnosis. To this aim Pattern Recognition approaches should be specifically studied and coupled with Cognitive and neuro-muscular generation models.

IV.CONCLUSION

A brief overview of the handwriting analysis approaches for early diagnosis, monitoring and tracking of neurodegenerative diseases is proposed in this paper. Specifically, Alzheimer and Parkinson diseases are taken into account. In addition to this, some light is thrown on challenges in design of automated system for early diagnosis of NGDs.

Handwriting analysis is an effective tool for dealing with the diagnosis and monitoring of the above cited diseases. However, some challenges which still needs to be dealt with are open, and are mainly related to-

(i) cardinalities, most of the datasets currently available does not allow pattern recognition tools to be useful

(ii) since hand-writing kinematics has shown to be useful for discriminating between patients and healthy controls, new protocols for the on-line acquisition of handwriting should be designed.

(iii) defining pattern recognition tools specifically devised for the automatic diagnosis and monitoring of neurodegenerative diseases.

REFERENCES
1. Allen, G.I., Tsukahara, N.: Cerebrocerebellar communication systems. Physiologi-cal Reviews 54(4), 957{1006 (1974)

2. Dasgupta, S., Wrgtter, F., Manoonpong, P.: Neuromodulatory adaptive combi-nation of correlation-based learning in cerebellum and reward-based learning in basal ganglia for goal-directed behavior control. Frontiers in Neural Circuits 8, 126 (2014)

3. Drotar, P., Mekyska, J., Rektorova, I., Masarova, L., Smekal, Z., Faundez-Zanuy, M.: Evaluation of handwriting kinematics and pressure for di erential diagnosis of parkinson's disease. Arti cial Intelligence in Medicine 67, 39{46 (2016)

4. Eichhorn, T.E., Gasser, T., Mai, N., Marquardt, C., Arnold, G., Schwarz, J., Oertel, W.H.: Computational analysis of open loop handwriting movements in parkinson's disease: A rapid method to detect dopamimetic e ects. Movement Disorders 11(3), 289{297 (1996)

5. Grossberg, S., Paine, R.: A neural model of cortico-cerebellar interactions during attentive imitation and predictive learning of sequential handwriting movements. Neural Netw. 13(8-9), 999{1046 (2000)

6. Hikosaka, O., Nakahara, H., Rand, M., Sakai, K., Lu, X., Nakamura, K., Miyachi, S., Doya, K.: Parallel neural networks for learning sequential procedures. Trends in Neurosciences 22(10), 464{471 (1999)

7. Horowski, R., Horowski, L., Vogel, S., Poewe, W., Kielhorn, F.: An essay on Wilhelm von humboldt and the shaking palsy: rst comprehensive description of parkinson's disease by a patient. Neurology 45(3), 565{568 (1995)

8. Hughes, J.C., Graham, N., Patterson, K., Hodges, J.R.: Dysgraphia in mild de-mentia of alzheimer's type. Neuropsychologia 35(4), 533 { 545 (1997)

9. Impedovo, D., Pirlo, G., Mangini, F.M., Barbuzzi, D., Rollo, A., Balestrucci, A., Impedovo, S., Sarcinella, L., O'Reilly, C., Plamondon, R.: Writing Generation Model for Health Care Neuromuscular System Investigation, pp. 137{148. Springer International Publishing (2014)

10. Kandel, E.R., Schwartz, J.H., Jessell, T.M.: Principles of Neural Science. McGraw-Hill Medical, 4th edn. (Jul 2000)

11. Letanneux, A., Danna, J., Velay, J.L., Viallet, F., Pinto, S.: From micrographia to parkinson's disease dysgraphia. Movement Disorders 29(12), 1467{1475 (2014)

12. Nakahara, H., Doya, K., Hikosaka, O.: Parallel cortico-basal ganglia mechanisms for acquisition and execution of visuomotor sequences - a computational approach. J Cogn Neurosci. 13(5), 626{647 (2001)

13. Neils-Strunjas, J., Groves-Wright, K., Mashima, P., Harnish, S.: Dysgraphia in

    Alzheimer's disease: a review for clinical and research purposes. J Speech Lang Hear Res 49(6), 1313{30 (2006)

14. Onofri, E., Mercuri, M., Salesi, M., Ricciardi, M., Archer, T.: Dysgraphia in re-lation to cognitive performance in patients with Alzheimer's disease. Journal of Intellectual Disability - Diagnosis and Treatment 1, 113{124 (2013)

15. OReilly, C., Plamondon, R.: Development of a sigmalognormal representation for on-line signatures. Pattern Recognition 42(12), 3324 { 3337 (2009)

16. Pereira, C.R., Pereira, D.R., da Silva, F.A., Hook, C., Weber, S.A.T., Pereira, L.A.M., Papa, J.P.: A step towards the automated diagnosis of parkinson's disease: Analyzing handwriting movements. In: 28th IEEE International Symposium on Computer-Based Medical Systems, CBMS 2015, Sao Carlos, Brazil, June 22-25, 2015. pp. 171{176 (2015)

17. Pirlo, G., Cabrera, M.D., Ferrer-Ballester, M.A., Impedovo, D., Occhionero, F., Zurlo, U.: Early diagnosis of neurodegenerative diseases by handwritten signature analysis. In: ICIAP Workshops. pp. 290{297 (2015)

18. Plamondon, R.: Handwriting generation: the delta-lognormal theory. In: Proc. Of the 4th International Workshop on Frontiers in Handwriting Recognition. pp. 1{10 (1994)

19. Plamondon, R.: A kinematic theory of rapid human movements. i. movement rep-resentation and generation. Biol. Cybern. 72(4), 295{307 (1995)

20. Plamondon, R.: A kinematic theory of rapid human movements. ii. movement time and control. Biol. Cybern. 72(4), 295307 (1995)

21. Platel, H., Lambert, J., Eustache, F., Cadet, B., Dary, M., Viader, F., Lechevalier, B.: Characteristics and evolution of writing impairment in alzheimer's disease. Neuropsychologia 31(11), 1147{58 (1993)

22. Poluha, P., Teulings, H., Brookshire, R.: Handwriting and speech changes across the levodopa cycle in parkinsons disease. Acta Psychologica 100(1), 71 { 84 (1998)

23. Rosenblum, S., Samuel, M., Zlotnik, S., Erikh, I., Schlesinger, I.: Handwriting as an objective tool for parkinsons disease diagnosis. Journal of Neurology 260, 2357{ 2361 (2013)

24. Schr•oter, A., Mergl, R., B•urger, K., Hampel, H., M•oller, H.J., Hegerl, U.: Kine-matic analysis of handwriting movements in patients with alzheimer's disease, mild cognitive impairment, depression and healthy subjects. Dementia and geriatric cog-nitive disorders 15(3), 132{42 (2003)

25. Small, J., Sandhu, N.: Episodic and semantic memory in uences on picture naming in alzheimer's disease. Brain Lang. 104(1), 1{9 (1997)

26. Smits, E.J., Tolonen, A.J., Cluitmans, L., van Gils, M., Conway, B.A., Zietsma, R.C., Leenders, K.L., Maurits, N.M.: Standardized handwriting to assess bradyki-nesia, micrographia and tremor in parkinson's disease. PLOS One 9(5) (May 2014)

27. Teulings, H.L., Contreras-Vidal, J.L., Stelmach, G.E., Adler, C.H.: Adaptation of handwriting size under distorted visual feedback in patients with parkinson's disease and elderly and young controls. Journal of Neurology, Neurosurgery & Psychiatry 72(3), 315{324 (2002)

28. Tseng, M.H., Cermak, S.A.: The influence of ergonomic factors and perceptual motor abilities on handwriting performance. American Journal of Occupational Therapy 47(10), 919{926 (1993)

29. C. De Stefano, F. Fontanella, D. Impedovo and A. Scotto di Freca, G. Pirlo, A Brief Overview on Handwriting Analysis for Neurodegenerative Disease Diagnosys, D. Impedovo and G. Pirlo (Eds.), Workshop on Artificial Intelligence with Application in Health, Bari, Italy, November 14, 2017.