COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 136 (2016) 79–88

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

A new computer vision-based approach to aid the diagnosis of Parkinson's disease

Clayton R. Pereira [a], *Danilo R. Pereira* [b], *Francisco A. Silva* [b], *João P. Masieiro* [b], *Silke A.T. Weber* [c], *Christian Hook* [d], *João P. Papa* [e,*]

[a] *Department of Computing, Federal University of São Carlos, Brazil*
[b] *University of Western São Paulo, Brazil*
[c] *Department of Ophthalmology and Otorhinolaryngology, São Paulo State University, Brazil*
[d] *Ostbayerische Technische Hochschule, Germany*
[e] *Department of Computing, São Paulo State University, Brazil*

ARTICLE INFO

Article history:
Received 2 March 2016
Received in revised form
9 June 2016
Accepted 11 August 2016

Keywords:
Parkinson's disease
Pattern recognition
Micrography

ABSTRACT

Background and Objective: Even today, pointing out an exam that can diagnose a patient with Parkinson's disease (PD) accurately enough is not an easy task. Although a number of techniques have been used in search for a more precise method, detecting such illness and measuring its level of severity early enough to postpone its side effects are not straightforward. In this work, after reviewing a considerable number of works, we conclude that only a few techniques address the problem of PD recognition by means of micrography using computer vision techniques. Therefore, we consider the problem of aiding automatic PD diagnosis by means of spirals and meanders filled out in forms, which are then compared with the template for feature extraction.

Methods: In our work, both the template and the drawings are identified and separated automatically using image processing techniques, thus needing no user intervention. Since we have no registered images, the idea is to obtain a suitable representation of both template and drawings using the very same approach for all images in a fast and accurate approach.

Results: The results have shown that we can obtain very reasonable recognition rates (around ≈67%), with the most accurate class being the one represented by the patients, which outnumbered the control individuals in the proposed dataset.

Conclusions: The proposed approach seemed to be suitable for aiding in automatic PD diagnosis by means of computer vision and machine learning techniques. Also, meander images play an important role, leading to higher accuracies than spiral images. We also observed that the main problem in detecting PD is the patients in the early stages, who can draw near-perfect objects, which are very similar to the ones made by control patients.

* *Corresponding author.* Department of Computing, São Paulo State University, Brazil. Fax: +55-14-3103-6079.
E-mail address: papa@fc.unesp.br (J.P. Papa).

http://dx.doi.org/10.1016/j.cmpb.2016.08.005
0169-2607/

1. Introduction

Parkinson's disease (PD) is a degenerative, chronic, and progressive illness that may cause tremors, slowness of movement, muscle stiffness, and changes in speech and writing skills due to the neurological disorder [1]. PD was first described by the English physician James Parkinson [2], with its symptoms being well-known in the scientific community. However, to diagnose Parkinson's disease with a reliable recognition rate in its early stages is still unheard of. Moreover, it is not straightforward to establish the PD level soon after its diagnosis.

Parkinson's disease occurs when nerve cells that produce dopamine are destroyed, a process that is performed slowly, thus characterizing the progression of this disease. With the absence of such a substance, the nerve cells can no longer send messages properly, causing many other symptoms such as depression, sleep disturbances, memory impairment and autonomic nervous system disorders. In some cases, Parkinson's disease may be trigged by hereditary causes [1].

In the last decades, some works attempted at designing solutions to aid PD diagnosis. Expert systems based on machine learning techniques have been employed to this purpose, showing promising results [3]. Generally, these works are signal analysis-oriented, which means one can use the patient's voice to assess the level of the illness [4,5], since the voice capability is gradually compromised by PD. Little et al. [4], for instance, presented a dataset composed of biomedical voice measurements from 31 male and female subjects, of which 23 patients were diagnosed with PD and 8 were healthy subjects. The authors introduced a new measure of dysphonia called Pitch Period Entropy, which seems to be more robust in identifying changes in the speech, since approximately 90% of PD patients exhibit some form of vocal impairment [6,7].

In the work conducted by Zhao et al. [8], five patients and seven healthy individuals were used to recognize Parkinson's disease by means of voice analysis. In order to fulfill this purpose, voices of the patients were recorded using an Isomax EarSet E60P5L microphone; the recording sessions lasted around 25 minutes each, and the authors used a total of 50 prerecorded prompts consisting of emotional sentences spoken by a professional actress. Tsanas et al. [9] evaluated different algorithms based on dysphonia measures aiming at PD recognition. A total of 132 acoustic features were initially used for further feature selection, and the authors concluded that the dysphonia information and the existing features end up helping PD recognition. Harel et al. [10] claimed that PD symptoms are detectable up to five years prior to clinical diagnosis, and symptoms presented in speech include reduced loudness, increased vocal tremor, and breathiness. In their work, the authors used a dataset of the National Center for Voice and Speech, which comprises 263 phonations from 43 subjects (17 females and 26 males, of which 10 were healthy controls and 33 were diagnosed with PD).

Since one of the first manifestation of Parkinson's Disease is the deterioration of handwriting, the micrography (a writing exam) is another approach widely used for the diagnosis of Parkinson's disease [11]. This technique is considered an objective measure, since a PD patient possibly features the reduction of calligraphy size, as well as the hand tremors. Nowadays, this procedure is often conducted by filling out some specific forms. Rosenblum et al. [12] suggested that writing exams can be used to distinguish PD patients from healthy individuals. The authors employed the following methodology to support their assumption: 20 PD patients and 20 control individuals were asked to write their names and addresses in a piece of paper attached to a digital table. Further, for each stroke, the mean pressure and velocity were measured in order to compute spatial and temporal information. The authors presented very good recognition rates, with 97.5% of the participants classified correctly (100% of the control individuals, and 95% of PD patients). Later on, Drotár et al. [13] claimed that movement during handwriting of a text consists not only from the on-surface movements of the hand, but also from the in-air trajectories performed when the hand moves in the air from one stroke to the next. The authors demonstrated the assessment of in-air hand movements during sentence handwriting has a higher impact than the pure evaluation of on surface movements, leading to classification accuracies of 84% and 78%, respectively.

Machine learning-based techniques have also been applied to help automatic PD recognition. Spadotto et al. [14], for instance, introduced the Optimum-Path Forest (OPF) [15,16] classifier to the aforementioned context. Later on, Spadotto et al. [17] proposed an evolutionary-based approach to select the most discriminative set of features in order to improve PD recognition rates. Gharehchopogh and Mohammadi [18] used Artificial Neural Networks with Multi-Layer Perceptron to diagnose the effects caused by Parkinson's disease. Pan et al. [19] analyzed the performance of Support Vector Machines with Radial Basis Function in order to compare the onset of tremor in patients with Parkinson's disease. Hariharan et al. [20] developed a new feature weighting method using Model-based clustering (Gaussian mixture model) in order to enrich the discriminative ability of the dysphonia-based features, thus achieving 100% of classification accuracy. Recently, Peker et al. [21] used sound-based features and complex-valued neural networks to aid PD diagnosis as well.

However, although many works deal with voice- and speech-driven information, there is a large number of writing exams out there that can give us valuable information about the development of Parkinson's Disease, since it is cheaper and easier to acquire such sort of exam. Moreover, most hospitals and clinics have writing exams by hand only, which means they need to be digitized prior to information extraction. Usually, the patients are asked to draw spirals and meanders, which are then compared against the templates. Very recently, Pereira et al. [22] proposed to extract features from writing exams using image processing techniques, achieving around 79% of recognition rates, which is considered very reasonable. The authors also designed and made available a dataset called "HandPD" with all images and features extracted.[1] However, they employed "spirals" drawings only.

In this paper, we extended the work of Pereira et al. [22] by presenting the following contributions: (i) a deeper analysis and explanation about the feature extraction process, as well as a tremor-based feature is also analyzed; (ii) we considered both spirals and meanders for the classification process; and (iii) we

[1] http://wwwp.fc.unesp.br/~papa/pub/datasets/Handpd/.