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Handwritten dynamics assessment through convolutional neural networks: An application to Parkinson's disease identification

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ABSTRACT

Background and objective: Parkinson's disease (PD) is considered a degenerative disorder that affects the motor system, which may cause tremors, micrography, and the freezing of gait. Although PD is related to the lack of dopamine, the triggering process of its development is not fully understood yet.
Methods: In this work, we introduce convolutional neural networks to learn features from images produced by handwritten dynamics, which capture different information during the individual's assessment. Additionally, we make available a dataset composed of images and signal-based data to foster the research related to computer-aided PD diagnosis.
Results: The proposed approach was compared against raw data and texture-based descriptors, showing suitable results, mainly in the context of early stage detection, with results nearly to 95%.
Conclusions: The analysis of handwritten dynamics using deep learning techniques showed to be useful for automatic Parkinson's disease identification, as well as it can outperform handcrafted features.

1. Introduction

Parkinson's disease (PD) is a neurodegenerative disease that affects millions of people worldwide, and it has no cure. The main reported symptoms are often related to the freezing of gate, tremors, and alterations in gait and speech, to name a few. Such illness usually impacts daily activities and reduces the quality of life concerning patients and their families [1–4].

A number of drugs have been developed to cope with the disease, but their usage along the years might hasten neurodegeneration [5]. The main problem regarding PD concerns its detection in early stages, since it is unknown the real situations that trigger Parkinson's Disease. Therefore, researchers from different areas aim at pushing together their skills and helping each other to better understand such illness. In this context, machine learning techniques seem to be quite useful since they can learn intrinsic information that sometimes are not perceived by humans.

Das [6], for instance, presented a comparison among some classification techniques concerning PD diagnosis, achieving around 92.2% of classification accuracy by means of Neural Networks. Spadotto et al. [7] introduced the Optimum-Path Forest (OPF) [8,9] in the context of automatic PD identification, and Gharehchopogh and Mohammadi [10] used Artificial Neural Networks with Multi-Layer Perceptron to diagnose the effects caused by Parkinson's Disease. Spadotto et al. [11] also considered using a meta-heuristic-driven feature selection aiming at recognizing such illness.

Memedi et al. [12] measured the disease progression in PD patients, which were asked to perform some handwritten exams at home, and Drotár et al. [13] and Taleb et al. [14] also considered handwriting features for PD evaluation, but focused on finding a subset of that features that really matter when diagnosing PD. Lones et al. [15] employed evolutionary algorithms for combining classifiers aiming at the automatic identification of Parkinson's Disease. Pan et al. [16] evaluated the performance of support vector machines with radial basis function to compare the onset of tremors in patients with PD.

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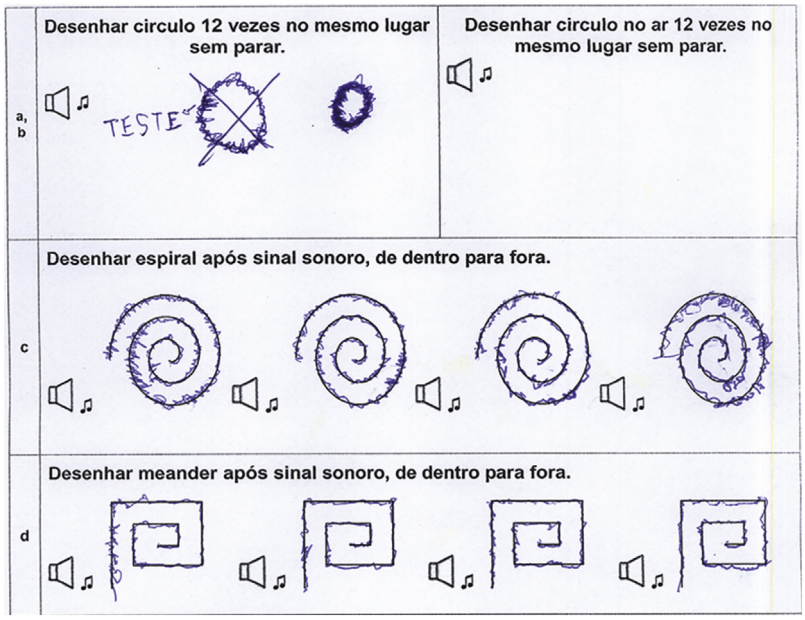

Fig. 1. Handwritten exam adapted from Pereira et al. [21].

Peker et al. [17] employed information from biomedical sound measurements and complex-valued neural networks to aid PD diagnosis as well, and Hariharan et al. [18] developed a new feature weighting method using Model-based clustering (Gaussian mixture model) to enrich the discriminative ability of some dysphonia-based features, achieving 100% of classification accuracy. Very recently, Drotár et al. [19] presented the PaHaW Parkinson's disease handwriting database, which consists of handwriting samples from Parkinson's disease patients and healthy controls. Their goal was to show that both kinematic and pressure features in handwriting can be used for automatic PD diagnosis, and Sadikov et al. [20] aimed at detecting early Parkinson's disease motoric symptoms by means of spirography, i.e., the task of drawing geometrical figures.

Pereira et al. [21] proposed to aid PD diagnosis using images obtained from handwriting movements, as well as they designed a public dataset with hundreds of images containing handwriting drawings from healthy individuals and patients. Later on, the same research group also presented a study that employed Convolutional Neural Networks to learn features from handwritten exams for automatic PD identification [22–24]. Peuker et al. [25] used the signals extracted from a smartpen to perform PD identification, obtaining very suitable results. However, the authors extracted features using a sequential-driven feature selection algorithm, which may be quite costly in terms of computational burden for large datasets.

In this work, we proposed to learn features obtained from handwritten dynamics using a convolutional neural network (CNN) [26], which can process information through a set of layers, being each one in charge of learning a different and finer representation. Another contribution is to make available a dataset composed of the signals extracted from patients and healthy individuals through the smartpen, which is called "NewHandPD"[1]. Additionally, we showed how to improve PD identification by means of an ensemble of CNNs, which were trained over six different handwritten exams: (i) drawing circles on the paper, (ii) drawing circles in the air, (iii) spirals, (iv) meanders, (v) left-wrist movements and (vi) right-wrist movements.

The remainder of this paper is organized as follows. Section 2 presents the methodology employed in this work, as well as the proposed dataset. Section 3 presents the experimental results, and Section 4 states conclusions and future works.

2. Methodology

In this section, we present the methodology used to create the dataset, as well as the proposed approach to analyzing the handwritten dynamics based on Convolutional Neural Networks.

2.1. HandPD dataset

The writing of parkinsonian patients usually faces the so-called micro-graphing, with reduced movement amplitudes, slowness, and rigidity [27]. Also, it is not straightforward to highlight a specific exam that can identify an early-stage patient. Another problem concerns the fact that PD is usually misidentified with other brain disorders quite oftenly.

Recently, Pereira et al. [21] made available a dataset concerning images acquired during handwriting exams, as the one depicted in Fig. 1. The idea of the form is to ask a person to perform some specific tasks that are supposed nontrivial to PD patients, including to trace some geometric shapes and conducting the so-called "diadochokinesis test", which is a test where the individual holds the pen with straight arms and perform hand-wrist movements.

Table 1
Description of the dataset used in this work.

Dataset			
Control		Patient	
Male	Female	Male	Female
6	12	59	15
Average age			
44.22 ± 16.53		58.75 ± 7.51	

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

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