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Automatic non-linear analysis of non-invasive writing signals, applied to essential tremor

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ABSTRACT

Essential tremor (ET) in the western world is the most common movement disorder, and 50–70% of essential tremor cases are estimated to be genetic in origin [14]. This work on selection of nonlinear biomarkers derived from drawings and handwriting is part of a wider cross-study for the diagnosis of essential tremor led by Biodonostia Institute. These biomarkers include not only classic linear features, but also non-linear: fractal dimension and entropy. The presence of integrated features of other diseases such as stress is also analyzed. In future works, these new biomarkers will be integrated with the ones obtained in the wider study of Biodonostia. Note that the use of these methods provide undoubted benefits towards the development of more sustainable, low-cost, high-quality, and non-invasive technologies. These systems are easily adaptable to the user and environment, and can be very useful in real complex environments with regard to a social and economic point of view.

1. Introduction

Essential tremor is a condition that affects individuals worldwide. The prevalence of essential tremor (ET) in the western world is about 0.3–4.0%, 40-year old males and females are affected more or less equally with an incidence of 23.7 per 100,000 people per year. Studies in the elderly suggest that prevalence in these patients ranges from 3.9% to 14.0%. 50–70% of essential tremor cases being estimated to be genetic in origin [14]. Essential tremor is a rhythmic tremor (4–12 Hz) that occurs only when the affected muscle is exerting effort. Physical or mental stress could worsen the tremor, and the prevalence of Parkinson's disease (PD) in people with essential tremor is greater than in the general population. Parkinson's disease and parkinsonism can also occur simultaneously with essential tremor. As far as symptoms are concerned, hand

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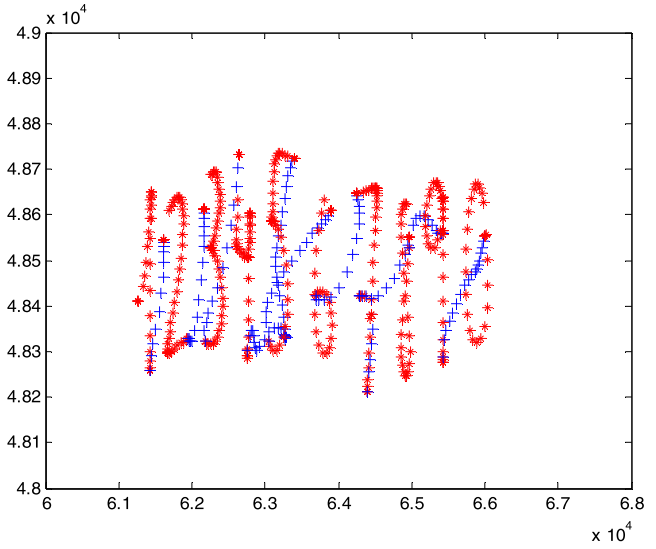

Fig. 1. Example of handwritten numerical digits in a digitizing tablet. Red asterisks (∗) represent pen-down information, and blue crosses (+) the pen-up information.

tremor predominates, as it does in Parkinson's disease, and occurs in nearly all cases, followed by: head tremor, voice tremor, neck, face, leg, tongue, and trunk tremor. Most tremors occur in association with hand tremor. Walking difficulties in essential tremor are common as well. PD and ET can appear in individuals of the same family [14].

The clinical hallmark and earliest manifestation of the disorder is essential in order to manage and palliate symptoms. All these symptoms lead to impaired performance in everyday activities. In the past few years, approaches to the early diagnosis of ET have greatly advanced in the development of reliable clinical biomarkers. Despite the usefulness of biomarkers, the cost and the involved technology requirements make it impossible to apply such tests to all patients with motor disorders. Therefore, it is necessary to develop new non-invasive intelligent techniques of diagnosis in order to provide tools for early detection of disorders. These techniques involve speech analysis, handwriting, or drawing analysis, which are not perceived as a stressful test by the patient, so that non-technical staff in the habitual environments of the patient could use these methodologies without altering or blocking the patients' abilities. Moreover, these techniques are very low-cost and do not require extensive infrastructure or medical equipment, i.e. they are capable of yielding information easily, quickly, and inexpensively [9,11,12,25].

It is well established that handwritten tasks can be used for diagnosis of essential tremor. In the past, the analysis of handwriting was performed offline, and only the writing itself (strokes on the paper) were available for analysis. Nowadays, modern capturing devices, such as digitizing tablets and pens (with or without ink) can gather data without losing its temporal dimension. When spatio-temporal information is available, its analysis is referred to as online. Modern digitizing tablets gather the x and y coordinates that describe the movement of the writing device as it changes its position, and can also collect other data, such as the pressure exerted by the writing device on the writing surface, the azimuth, the angle of the pen in the horizontal plane, the altitude, or the angle of the pen with respect to the vertical axis (Figs. 1 and 2) [21]. Fig. 1 shows the acquisition of the ten digits from 1 to 0 using an Intuos Wacom 4 digitizing tablet. The tablet acquired 100 samples per second including the spatial coordinates (x, y), the pressure, and a couple of angles (see Fig. 2). The pen-up information is represented in Fig. 1 using blue crosses (+), and the pen-down is marked with red asterisks (∗). Our experiments on biometric recognition of people reveal that pen-up and pen-down information are complementary [21], and in fact contain a similar discriminative capability, even when using a database of 370 users [4,18,25].

Thus, the movements performed by the hand while writing a text can be classified into two groups: