

A novel analytical approach to assess dyskinesia in patients with Parkinson disease

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Abstract — A novel analytical methodology is presented aimed at the objective evaluation of dyskinetic movements which occur in Parkinson's disease. The methodology is based on the comparison between the harmonic contents of voluntary and non-voluntary movements, highlighting their correlation in terms of frequency and phase mismatches. Interestingly, we demonstrated that there is a time delay between these two kinds of movements. The dyskinesia was measured by means of low-cost and easy-to-use wearable electronics based on inertial sensor units.

Keywords—Wearable sensors; Parkinson's disease; Dyskinesia

I. INTRODUCTION

Parkinson's disease (PD) is a degenerative disorder of the central nervous system, clinically characterized by motor symptoms (tremor, rigidity, bradykinesia, postural instability and gait disturbance), and non-motor symptoms (cognitive impairment, autonomic dysfunction and sleep disorders). PD is the most common neurodegenerative disorder after Alzheimer's disease and has a prevalence that grows exponentially with aging, affecting about 1% of the population over 60 years and 4% of the population over 85 years [1].

Symptoms of PD can be clinically treated through the use of Levodopa, a precursor of Dopamine. Unfortunately, the chronic use of Levodopa leads to the onset of involuntary movements known as dyskinesia [2]. Approximately 30% of PD patients have dyskinesia in the first 5 years of treatment and, meaningfully, 59-100% in the first 10 years [3], [4]. Dyskinesia significantly impacts the quality of life of the individual, bringing fatigue, social isolation and depression [2], [5].

The clinical evaluation of dyskinesia is generally based on patient self-reporting, through diaries, or the use of different clinical assessment scales [6]–[9]. With regards of self-reporting, the major problem is that generally the patients have the tendency to underestimate the problem. With regards of the clinical assessment scales, the major problem is that they are performed on the basis of limited time of an outpatient visit, which can be poorly representative of the daily burden of motor fluctuation. Consequently, the objective assessment of dyskinesia is currently a challenging goal for movement disorder specialists, and has become increasingly urgent, given the growing number of drugs being developed in this regard [10].

In this scenario, a fundamental help comes from the recent development of inertial sensor electronics, with new devices which are smaller, cheaper, more precise and less cumbersome than before. Consequently, sensors are more and more adopted by different authors to measure motor skills in PD patients [11]–[15].

On the basis of the measurements obtained from the wearable electronics, some authors suggested the revealing of dyskinesia by means of some classifiers (in particular, random forest, neural networks, and naïve Bayes) [16]–[18], while others correlated some features extracted by sensors measurements to the clinical scales in order to assess dyskinesia severity [19]–[23]. In those works, data were collected both during outpatient evaluation and in the home setting.

Until now, no reliable method exists in clinical practice for dyskinesia evaluation. Moreover, the data collection methods greatly differ in the number of used sensors and in the position they are located on the patient's body. Moreover, none of the currently adopted method was able to separate the signals coming from voluntary movements and signals from non-voluntary ones, which overlap in frequency.

The dyskinesia is most often observed in the lower extremities of the body when the patient's attention is focused on the motor control of the upper extremities. In such a view, for our proposal, the key aspect we underline is related to the non-voluntary movements of the legs while the patient is voluntarily performing the pronation-supination of the hands (Fig. 1). So, here we adopted signal analysis techniques, in particular Fourier transformation and cross-correlation function, to assess dyskinesia relating it to the aspect of voluntary and non-voluntary movements.

II. CROSS-CORRELATION

Our proposal was to adopt a cross-correlation method in order to evaluate the degree of similarity among signals related to voluntary and involuntary movements, highlighting their characteristics in terms of frequency, phase mismatch and harmonic content.

The cross-correlation has been widely used in many engineering fields, including electronics, acoustics and geophysics, aimed at noise isolation, evaluation of signal similarity and event recognition. With correlation, one signal

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