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IFAC-PapersOnLine 49-19 (2016) 272–276

An Alternative Approach to Distinguish Movements of Parkinson Disease Patients

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Abstract: The set of the *motion mass* parameters, describing the amount and smoothness of movements, is employed as a main tool to demonstrate the differences between the patients with Parkinson disease and the group of healthy individuals, performing the Up-and-Go test. Unlike many existing results in this area, which are based on some features associated to the particular time instance, motion mass parameters are computed for the certain time interval and therefore describe movement in general. The main goal of the present study is to demonstrate that the motion mass parameters associated with the segments of the Up-and-Go test significantly differ between patients with Parkinson disease and healthy individuals.

Keywords: Motion mass, motion capture, motion analysis, Parkinson disease.

1. INTRODUCTION

The present study investigates applicability of the motion mass (MM) Nõmm and Toomela (2013) parameters to distinguish movements of the patients with Parkinson disease (PD) compared to those of healthy individuals. In Nõmm and Toomela (2013) the set of four parameters was used to describe amount and smoothness of the human arm movements performed during the learning process of ball throwing exercise. It was demonstrated that amount and smoothness of the right hand movements differ significantly in the beginning and in the end of the learning. Ability to demonstrate distinguishability of the MM parameters of movements in PD patients compared to healthy individuals would justify further research to model progression of PD by characteristics of motions.

PD is a neurodegenerative disease involving basal ganglia in brain, characterised clinically by rest tremor, slowing of movements and changes in gait patterns, with shorter steps, diminished concomitant movements, and freezing episodes with falls in later stages that may cause a remarkable disability. Objective measures to characterise movements in PD patients in details would allow to assess progression of the disease, and effectiveness of therapies see Berardelli et al. (2013). On the one hand majority of main-stream contributions devoted to the movement analysis of PD patients target to assess some feature of the movement, for example gait parameters are studied in Yoneyama et al. (2014) or Hundza et al. (2014), or use the analysis of the certain angle(s) see Manap et al. (2011). On the other hand application of MM parameters describes motion or certain segment of the movement in a more general way. The main features of Parkinson's disease are tremor, hypokinesia and bradykinesia, rigididy, and postural disorder, that cause impairment of motor performance due to slowness of movements. One of the most important functional tasks among daily activities is the gate that may be impaired in Parkinson's disease, resulting in a remarkable functional disability during progression of the disease, and affect the quality of life of patients, see Kalia and Lang (2015). Though the Unified Parkinson's Disease Rating Scale (UPDRS) that is used to assess the severity of the disease, includes separate items to rate certain movements, it is difficult to measure objectively complex tasks like the gait, to demonstrate dynamic changes during the course of Parkinson's disease, and effect of physiotherapy in improving the gait. This study aims to demonstrate that the motion mass parameters including smoothness and timing, measured by the Kinect system are relevant to differ movements speed and composition between Parkinsonian patients and controls (healthy individuals), and allow to assess the disease severity and progression of movement disorder, as well to demonstrated positive changes as a result of treatments.

The method proposed by the authors does not directly depend on the motion capture system. Within the present research Kinect device was used for motion capture. In spite of its simplicity it provides sufficient level of accuracy to be applied for motion analysis in different medical applications including Parkinson Disease. In Ťupa et al. (2015) and Cancela et al. (2014) Kinect is employed for

10.1016/j.ifacol.2016.10.546

gait assessment and recognition of Parkinson's disease. Parkinson patients movements during rehabilitation treatments are analyzed by Spasojević et al. (2015).

The following structure has been adopted for the paper. The formal problem statement is given in the Section 2. Section 3 describes experimental settings used to capture and process the movement data. Section 4 presents the main results of the paper. A short discussion of achieved results is hosted by the Section 5. Conclusions are drawn in the final section.

2. STATEMENT OF THE RESEARCH QUESTION

Main goal of the present study is to demonstrate that MM parameters describing movements of PD patients significantly differ from those of healthy individuals. In order to make this paper self-sufficient the notion of MM introduced by Nõmm and Toomela (2013) is described in the following subsection.

2.1 The notion of Motion Mass

Associate the set J to the human body, such that each point j_i corresponds (represents) one joint.

$$J = \{j_1, \dots, j_n\} \tag{1}$$

where n is the number of the joints of interest. Note that the specific exercises may focus the attention point on just one limb or some other group of joints, and therefore n may vary. With each joint j_i three following parameters may be associated. The length of trajectory T_{j_i} observed during the movement or exercise of the interest. *Acceleration mass* A_{j_i} the sum of the absolute values of the accelerations observed at each observation point (time instance). Euclidean distance E_{j_i} computed between the locations of given joint in the beginning end ending of the movement. *Trajectory Mass, Acceleration Mass* and *Combined Euclidean Distance* are defined for the set J as follows.

$$T_J = \sum_{i=1}^{n} T_{j_i} \tag{2}$$

$$A_J = \sum_{i=1}^{n} A_{j_i} \tag{3}$$

$$E_J = \sum_{i=1}^{n} E_{j_i} \tag{4}$$

Motion mass of the set of joints J is defined as

$$M_j = \{T_J, A_J, E_J, t\} \tag{5}$$

where t is the time length of the movement. In general MM parameters may be computed for any motion, or part of the movement and for any set of joints. For example in Nõmm and Toomela (2013) MM parameters were computed for the right hand,during ball throwing exercise.

Right hand motion during the ball throwing exercise is depicted in Figure 1. Bold lines represent initial and final positions of the hand. Dashed lines represent the distances between initial and final positions of the joints. In this case, the trajectory mass is the sum of the lengths of these three marked trajectories.

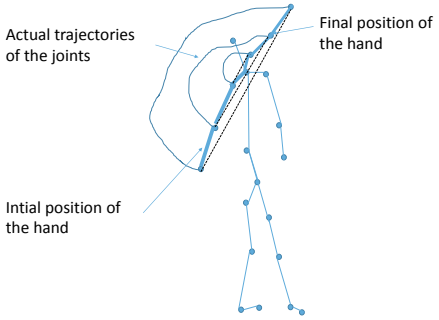

Fig. 1. Experimental setting

2.2 Up-and-go test

Up-and-go test is widely used in medicine to assess motor abilities of the patient, see Wall et al. (2000). The timed Up-and Go (TUG) test is not specifically used for the diagnosis of Parkinson's disease (PD) that was diagnosed by the QSBB diagnostic criteria, but the TUG demonstrates slowing of gait referring to the most specific symptoms of PD that cause functional impairment: hypokinesia and bradykinesia, often accompanied by postural instability, that may affect the gait and other movements. Therefore, the TUG is a relevant measure to differentiate gait between patients with PD and controls, as well changes of gait during progression of the disease, see Bohannon (2006). The present study is focused on a simple version of the test which requires a patient to seat on the chair, supported back by the back of chair. Once the patient is ready, the investigator gives the order and the patient follows the next steps: stands up, makes few steps, turns around, returns to the chair, turns around again, and seats down. This sequence may be repeated a few times depending on the purpose of the test and the condition of the patient. Usually the time is considered to be the most informative parameter which is used to assess the condition of the patient. For the purpose of the present pilot study, movements of standing-up and walking forward were selected to be captured as the basis for computing MM parameters. The choice of the movements is explained in Section 3. While only two movements were chosen to be captured, both the patients and healthy controls were requested to perform the entire cycle of the test three times. For the pilot groups of PD patients and controls (age and sex matched healthy individuals) demonstrate distinguishability of MM parameters computed during first two movements of the Up-and-Go Test.

3. EXPERIMENTAL SETTING

Motion capture was performed by the Microsoft Kinect sensor. While it is a relatively simple device, its precision has been evaluated and demonstrated to be enough to measure motor performance of PD patients, see Galna et al. (2014). Since the single Kinect sensor was designed to record movements from the enface when standing up and walking forward, the relevant movement segments were chosen to be analyzed. To perform the trials, the Kinect sensor was positioned on the height of $0.9m$ above the floor and $3.35m$ from the chair. The point where patient should turn and start to walk back towards the chair,