Quantitative movement assessment in Parkinson’s disease using vision and wearable sensors

S. Spasojević and J. Santos-Victor

ISR LISBOA / LARSys

Abstract

Evaluation of the patient’s condition in Parkinson’s disease (PD) and neurological disorders in general, is carried out using clinical scales that are prone to subjective rating and imprecise interpretation of patient’s performance. Recent developments in the field of affordable sensing technologies can potentially improve and support traditional evaluation techniques, relying on the objective approach. We aim to develop a non-invasive, portable and affordable system, suitable for home rehabilitation, which combines vision-based and wearable sensors (Fig. 1). We introduce a novel approach for examination and characterization of the rehabilitation movements, using quantitative descriptors. We propose novel scores called Movement Performance Indicators (MPIs), that are extracted directly from the sensor data and quantify the symmetry, velocity, and acceleration of the movement of different body/hand parts. Proposed MPIs can potentially be used by therapists for diagnosis and progress assessment.

Proposed approach for movement characterization

First, a set of rehabilitation exercises is defined, with the supervision of neurologists and therapists for the specific case of Parkinson’s disease. It comprises full-body movements measured with a Kinect device, fine hand movements, acquired with a data glove and arm/hand movements, collected with Myo sensor (Fig. 1). Then, the sensor data is used to compute 32 Movement Performance Indicators (MPIs), to assist the diagnosis and progress monitoring in Parkinson’s disease. The choice of MPIs was partly resulting from discussions with doctors, therapists, and other domain experts and partly from sensor data characteristics. The pipeline of the approach from the data acquisition to the final MPIs processing is given in Fig. 2. All together we have used 10 different MPIs that result from the combination of four measurement categories (speed, rigidity, the range of motion and symmetry) applied to 4 categories of full-body movements. Similarly to what we have done for full-body movements, we propose a new set of 15 MPIs to characterize the hand movements with respect to: (1) the range of motion of the characteristic hand and finger joints; (2) velocity values derived from abduction sensor angular data and (3) velocity and acceleration parameters between thumb and index finger tips estimated from the hand model. Since the wireless armband Myo sensor outputs the EMG signals, as well as the signals from accelerometer and gyroscope, MPIs are extracted in accordance with the time and frequency properties of the sensor signals such as signal amplitude and energy.

In total, 7 MPIs were designed to characterize those signals based on the window approach - temporal evolution of MPIs. All designed MPIs are tested in terms of the following clinically relevant aspects: (i) reliability; (ii) ability to discriminate between the patients and controls, and between the disease stages (support to diagnosis and monitoring, respectively); (iii) performance analysis and comparison between the left-hand and the right-hand movements across controls and patients, as well as between disease stage groups and (iv) correlation with clinical scales (tapping test and UPDRS-III Motor Score). MPIs obtained from the Myo armband sensor data turn out to be specifically significant for the analysis of the movement performance between left and right hand (Fig. 3). The mean MPI values for the left and right hand are similar in controls opposite to the patients (Fig. 3-a). The mean MPI values decrease from the first to the third stage and their difference between the left and the right hand increases (Fig. 3-b).

Results, conclusions and future work

We have defined a set of MPIs (32 in total: 10 for the full-body, 15 for the hand movements and 7 for arm/hand movements) that can be used for diagnosis, progress monitoring and evaluation of the motor symptoms (particularly bradykinesia – slowness of the movement). The design of these MPIs was grounded on the information provided by neurologists and therapists with the goal of delivering quantitative information about subject’s performance. Our results show that the proposed Movement Performance Indicators are relevant for the Parkinson’s disease assessment. This is further confirmed by correlation of the proposed indicators with clinical tapping test and UPDRS clinical scale. Classification results showed the potential of these indicators to discriminate between the patients and controls, as well as between the disease stages.

In the future work, we will focus on the aspects of balance and stability in PD. We are considering using a low-cost device for balance quantification. Furthermore, we plan to test our system on patients recovering from the stroke.

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