FCT Fundação para a Ciência e a Tecnologia

PhD Open Days

2nd edition!

16 - 17 MAY / SALÃO NOBRE

Combined vision and wearable sensors-based system for movement analysis in rehabilitation

Electrical and computer engineering

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Research motivation, objectives and methods

Traditional rehabilitation sessions are often a slow, tedious, disempowering and non-motivational process, supported by clinical assessment tools, i.e. evaluation scales that are prone to subjective rating and imprecise interpretation of patient's performance. Poor patient motivation and insufficient accuracy are thus critical factors that can be improved by new sensing/processing technologies.

We aim to develop a portable and affordable system (Fig. 1), suitable for home rehabilitation, which combines vision-based and wearable sensors. We introduce a novel approach for examining and characterizing the rehabilitation movements, using quantitative descriptors. We propose new Movement Performance Indicators (MPIs) that are extracted directly from sensor data and quantify the symmetry, velocity, and acceleration of the movement of different body/hand parts, and that can be used by therapists for diagnosis and progress assessment.

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 movements of grasping, pick and place, collected with Myo sensor (Fig. 2). Then, the sensor data is used to compute 25 Movement Performance Indicators (MPIs), to assist the diagnosis and progress monitoring in Parkinson's disease. A kinematic hand model is developed for data verification and as an additional resource for extracting additional movement information.

Proposed approach for movement characterization

We have used several MPIs that represent the movements of the different body parts (using the Kinect) or hands (using the data-glove) of a subject. The choice of MPIs was partly resulting from discussions with doctors, therapists, and other domain experts. In the following sections, we will detail how these MPIs were designed.

All together we have used 9 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 MPIs to characterize the hand movements with respect to: (1) range of motion of the characteristic hand and finger joints (for fingers flexion and extension movement and rotation of the hand); (2) velocity values derived from abduction sensor angular data (for finger expansion and contraction movement) and (3) velocity and acceleration parameters between thumb and index finger tips estimated from the hand model (for finger-tapping movement).

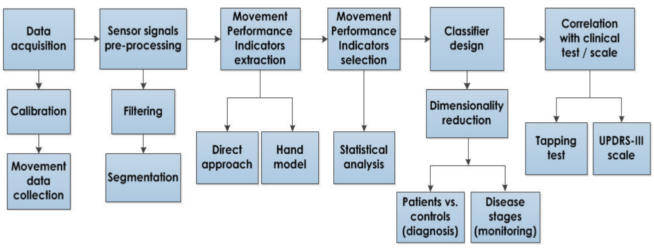

Figure 1. Proposed rehabilitation system structure

Figure 2. Sensors for the movement data acquisition: Kinect device (top), data glove (bottom left) and Myo sensor (bottom right)

Results, conclusions and future work

We have defined a set of MPIs (25 in total, 9 for the full-body and 16 for the hand movements) that can be used both for diagnosis and progress monitoring of PD during rehabilitation. 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. We have shown how these MPIs can be successfully used in practice. We address both full-body movements captured with the Kinect sensor and fine hand movements measured with the data glove.

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.

The proposed sensor system, along with the developed approach for rehabilitation movement analysis have a significant potential to support and advance traditional rehabilitation therapy. The main impact of our work is three-fold: enhancing the patient's quality of life, increasing the motivation for the therapy, supporting therapists during the diagnosis and monitoring evaluations by reducing subjectivity and imprecision and offering the possibility of being used at home for rehabilitation exercises in between sessions with doctors and therapists.

The analysis of the movements, collected with Myo sensor represents the future work. Myo is a lightweight, low-cost and portable device with Bluetooth connection for the data acquisition. It records eight-channel EMG data (muscle activity of the forearm muscles) and IMU data from the 3-axis accelerometer, gyroscope and magnetometer (acceleration, angular velocity and orientation data). As such, it represents suitable device to be included into our rehabilitation system.

This work is partially supported by the Portuguese FCT grant [UID/EEA/50009/2013]

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