Chapter 42

A Kinect–Based Biomechanical Assessment of Neurological Patients' Motor Performances for Domestic Rehabilitation

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ABSTRACT

Stroke is one of the main causes of disability in Western countries. Damaged brain areas are not able to provide the fine-tuned muscular control typical of human upper-limbs, resulting in many symptoms that affect consistently patients' daily-life activities. Neurological rehabilitation is a multifactorial process that aims at partially restoring the functional properties of the impaired limbs, taking advantage of neuroplasticity, i.e. the capability of re-aggregating neural networks in order to repair and substitute the damaged neural circuits. Recently, many virtual reality-based, robotic and exoskeleton approaches have been developed to exploit neuroplasticity and help conventional therapies in clinic. The effectiveness of such methods is only partly demonstrated. Patients' performances and clinical courses are assessed via a variety of complex and expensive sensors and time-consuming techniques: motion capture systems, EMG, EEG, MRI, interaction forces with the devices, clinical scales. Evidences show that benefits are proportional to treatment duration and intensity. Clinics can provide intensive assistance just for a limited amount of time. Thus, in order to preserve the benefits and increase them in time, the rehabilitative process should be continued at home. Simplicity, easiness of use, affordability, reliability and capability of storing logs of the rehabilitative sessions are the most important requirements in developing devices

to allow and facilitate domestic rehabilitation. Tracking systems are the primary sources of information to assess patients' motor performances. While expensive and sophisticated techniques can investigate neuroplasticity, neural activation (fMRI) and muscle stimulation patterns (EMG), the kinematic assessment is fundamental to provide basic but essential quantitative evaluations as range of motion, motor control quality and measurements of motion abilities. Microsoft Kinect and Kinect One are programmable and affordable tracking sensors enabling the measurement of the positions of human articular centers. They are widely used in rehabilitation, mainly for interacting with virtual environments and videogames, or training motor primitives and single joints. In this paper, the authors propose a novel use of the Kinect and Kinect One sensors in a medical protocol specifically developed to assess the motor control quality of neurologically impaired people. It is based on the evaluation of clinically meaningful synthetic performance indexes, derived from previously developed experiences in upper-limb robotic treatments. The protocol provides evaluations taking into account kinematics (articular clinical angles, velocities, accelerations), dynamics (shoulder torque and shoulder effort index), motor and postural control quantities (normalized jerk of the wrist, coefficient of periodicity, center of mass displacement). The Kinect-based platform performance evaluation was off-line compared with the measurements obtained with a marker-based motion tracking system during the execution of reaching tasks against gravity. Preliminary results based on the Kinect sensor suggest its efficacy in clustering healthy subjects and patients according to their motor performances, despite the less sensibility in respect to the marker-based system used for comparison. A software library to evaluate motor performances has been developed by the authors, implemented in different programming languages and is available for on-line use during training/evaluation sessions (Figure 1). The Kinect sensor coupled with the developed computational library is proposed as an assessment technology during domestic rehabilitation therapies with on-line feedback, enabled by an application featuring tracking, graphical representation and data logging. An experimental campaign is under development on post-stroke patients with the Kinect-One sensor. Preliminary results on patients with different residual functioning and level of impairment indicate the capability of the whole system in discriminating motor performances.

INTRODUCTION

Stroke is one of the main causes of disability in Western countries (Mill´an, 2006). Impaired motor control of the upper-limb is one of the most frequent consequences of stroke. Damaged brain areas are not able to provide the fine-tuned muscular control typical of human upper-limbs, resulting in many symptoms that consistently affect patients' daily-life activities (Pang, 2006; Bastian, 2000; Lum, 2004; Krebs, 2012). Patients affected by motor impairment are severely damaged in their everyday life, since their autonomy is compromised even for simple gestures.

Rehabilitation is a process that aims at taking advantage of neuroplasticity, that is the capability of the central nervous system to rearrange neural pathways to learn (or re-learn) muscular stimulation patterns. Such capability is thus oriented towards an organization process whose aim is the production of functional movement. Multidisciplinary rehabilitation techniques and approaches have been developed: traditional occupational physiotherapy, pharmacological and surgical interventions are supported by virtual reality gaming and feedback environments, robotic and exoskeleton-assisted (Figure 2) therapies aiming at stimulating and motivating patients by providing them tools to execute motor tasks repeatedly.

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