Post-stroke patients functional task characterization through accelerometry data for rehabilitation intervention and monitoring

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Abstract

An increasing ageing society and consequently rising number of post-stroke related neurological dysfunction patients are forcing the rehabilitation field to adapt to ever-growing demands. Compensatory movements related to available motor strategies, can be observed in post-stroke patients when performing functional tasks due to a pathological synergy as in reaching for an object. Studies of post-stroke motor recovery suggest that such maladaptive strategies may limit the plasticity of the nervous system to enhance neuromotor recovery. Strategies for rehabilitation protocols monitoring and validation are presently a necessity, moreover considering data recording is often absent of the rehabilitation process or subjective in nature. Characterization strategies of patient performance during functional task are key aspects for clinical protocols validation, progress monitoring and methodologies comparison. This project seeks to characterize patient's upper limb performance through accelerometry, gathered with a low-cost wearable system, for compensatory movement avoidance through feedback response.

1 Introduction

According to the World Health Organization (WHO), 15 million people worldwide suffer a stroke each year, being the leading cause of disability in adult population. Stroke is defined as an acute neurological dysfunction of vascular origin with rapid onset of signs and symptoms according to the committed areas of the brain. As epidemiological studies show, disability following stroke appears, albeit not only, but most evidently, in the form of neurological dysfunctions and reduced ability to actively engage in activities of daily living, justifying the need for intervention [1]. Economic related data reveals that in several countries 5% of the healthcare budget is allocated to stroke related costs, concerning not only the acute phase but also the subsequent, often very prolonged rehabilitation period [2]. Despite its relevant costs, agreement exists in the importance to continue to address the management of the *sequelae* of stroke. In fact, during the past decades, dramatic improvements have been made in this area and convincing scientific evidence now exists that stroke rehabilitation programs are effective at restoring functional abilities and reducing external dependency [3]. The main obstacle encountered by therapists in clinical practice is establishing an effective bridge between the results obtained during the studies and its efficient applicability at clinical environments [4].

Impairment of upper limb function is one of the most common deficits following stroke, specifically at the middle cerebral artery (MCA) territory. Specific rehabilitation remains challenging to a significant extent to date, with little agreement on the procedures to be followed, despite ongoing published guidelines containing recommendations on interventions and assessment strategies targeted towards the diverse areas of post-stroke disability [5]. The predominantly affected arm, contra-lateral to the committed hemisphere, may present muscular weakness; abnormal muscle tone, postural adjustments, and movement synergies; biomechanical impairments at joints and/or soft tissues level; incorrect timing of components within a movement pattern and loss of interjoint coordination [6]. In face of the before mentioned, it is often identified in post-stroke patients when attempting to move, as in for reaching an object, the emergence of compensations related to the available motor strategies and expressed in form of a pathological synergy [7].

Upper limb movement characterization has not received, until recently, much attention from researchers and physicians when compared to gait analysis. It is thanks to advances in microelectromechanical systems (MEMS), microelectronics, wireless communication devices, and monitoring solutions in general, that an increasing interest as been observe in the characterization and pattern determination of varying human activities in daily-life, sports, work related scenarios, rehabilitation, etc. Accelerometers and gyroscopes are proving to be a useful alternative to complex video-based movement recognition systems, not only for their low-cost and portable nature, but also due to their reduced processing overhead, making them candidates for feedback and wearable solutions.

1.1System Description

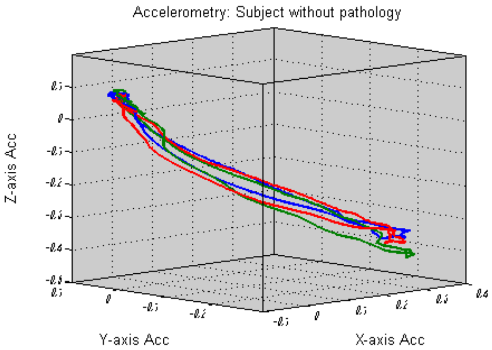
A simple wearable monitoring device, named W2M2 (Wireless Wearable Modular Monitoring), was design and implement for inertial data capturing. The device was based on commercially available components that could be assembled in a fast manner, without extensive knowledge of electronics; seeking to reduce overdependence on collaborating engineers. The module's main component, the Arduino FIO, is accessible at low cost and can be used with a reduced learning curve; additionally, the ADXL345 3-axis accelerometer break-out board was used combined with a XBEE based wireless interface, transforming the module in a portable, wireless adaptable resource.

2 Methodology

As reaching is the most common upper-limb human gesture, one can understand the great amount of interest devoted to its analysis, having some studies reported the expected components of movement, when target is placed in middle line and in healthy population: elbow flexion at the beginning of sequence, followed by combined shoulder flexion, shoulder horizontal adduction and elbow extension during the middle and final phases of the reach. Each subject was assessed in sitting position, with a table placed in front of them, at a height corresponding to the alignment of the iliac crests. The table limit was coincident with the distal border of the subject's thigh, so as not to interfere with the arm trajectory. The subjects were instructed to reach and press a target placed ipsilaterally to the upper limb in study, in groups of three repetitions (as to avoid variations due to fatigue) separated by one minute rest period. After a physiological study of the target area and experimental trial of sensor positioning for assured subject upper limb mobility and comfort, the following positions were considered P1, placed under the acromion, following the line that connects the lateral epicondyle and the acromion; P2, placed on the middle point between lateral epicondyle and the acromion; P3, immediately above lateral epicondyle, in alignment with acromion; P4, immediately below the lateral epicondyle, after elbow articulation; P5 is in the trunk on the T12.

The accelerometers data can be captured at varying frequencies up to approximately 100 Hz, which is then buffered and transmitted wirelessly; while a moving average smoothes the signal in order to reduce the influence of noise and oscillations. A window differentiation function was applied; used for automatic movement start and end determination. Additional plus/minus pseudo-envelope functions were generated through a moving window standard deviation approach, in order to provide references of signal stability.

The previously referred data undergoes a number of feature extraction procedures in order to provide information such as repeatability, smoothness, variation factors, timing components, etc., which the study intends to correlated with perceived pathologies by physicians and physiotherapist, in order to provide a quantifiable approach to compensatory and pathological movement determination. An example of three repetitions of the same functional task (reach, press and return) by a subject without pathology and a subject with pathology can be seen on Figure 1, illustrating the difference in perceived repeatability and pattern of the accelerometry data, as well as its promising use for pathology diagnosis. Other research objectives focus on the implementation of pattern recognition strategies for feedback during rehabilitation sessions for remote and home-based scenarios.



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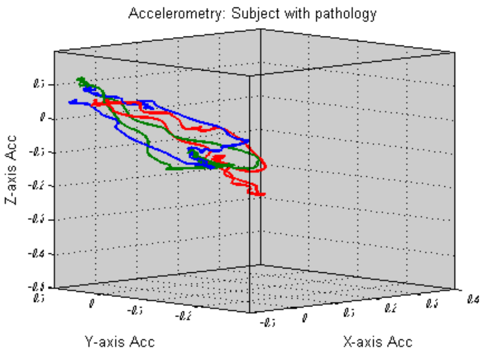

(b)

Figure 1: Three independent accelerometry for reach-press-return functional task from sitting position. a) Subject without pathology b) Subject with pathology.

A time and amplitude normalization approach permits comparison of a subjects movements over time or against other subjects, contributing to an improve progress monitoring and rehabilitation strategies validation. Figure 2, presents repetitions of two subjects with pathologies (black lines) versus a subject without pathologies (red line) used as a reference. The graphs illustrate the importance of a reference pattern establishment for appropriate formulation of comparison strategies for progress monitoring, diagnosis, etc.

3 Conclusions

Nowadays, post-stroke rehabilitation therapy is dictated mainly by qualitative analysis and assessment tools which rely on physiotherapists' assessment skills. Effective evaluation and monitoring constitute key factors of the overall rehabilitation process, representing a forward step in the clinical reasoning process which ultimately contributes to enhance patients' potential for recovery. The present study, although preliminary, shows potential for upper-limb movement dysfunctions characterization through compensation components discrimination within movement patterns. Future research seek the development of a quantitative based assessment and progress monitoring that can be combined with mathematical and biomechanical models, therapeutic strategy formulation, validation and diagnosis; including remote and home based device design and therapeutic protocol development.

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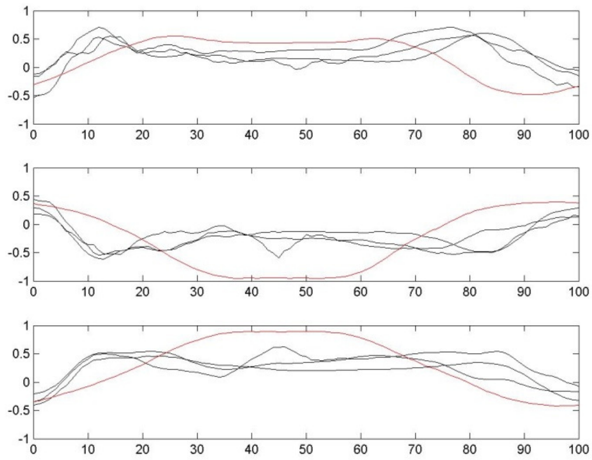

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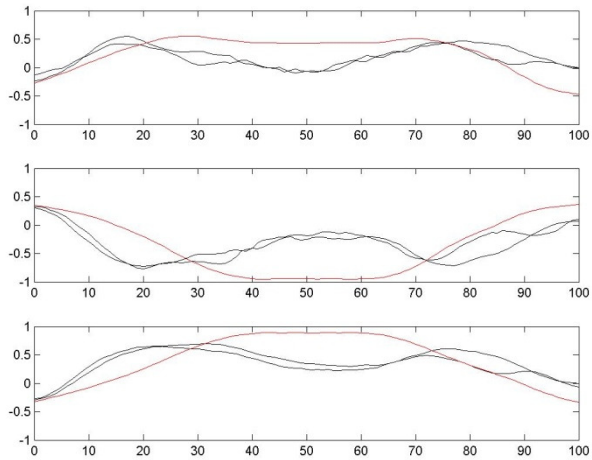

(b)

Figure 2: Comparison of accelerometry for reach-press-return functional task from sitting position. a) Subject A versus reference b) Subject B versus reference.

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