Sensors for triggering practical Functional Electrical Stimulation walking systems

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1. Introduction

Functional Electrical Stimulation (FES) techniques have shown significant improvement in mobility and functionality to many patients with pathological gait resulting from upper motor neurological injuries such as stroke, Multiple Sclerosis (MS), etc. Effective functioning of FES walking systems relies on accurate and reliable detection of gait events (i.e heel rise and heel strike) which depends on the type of sensors and the detection algorithm used.

2. Aims

The aim of this paper is to review the literature in the field of FES sensors to compare the performances, reliability, and practicality of the different sensing techniques and the detection algorithms associated with them in order to identify the best options available currently for next generation FES walking systems.

3. Methods

A literature search has been performed in the electronic data base PubMed. The review focused on papers reporting gait event detection techniques used for FES walking systems published over the last two decades up to December 2009.

4. Results

The literature search resulted in identifying six types of sensors used for FES walking systems found in 64 papers reviewed; Force Sensing Resistors (FSR), Accelerometers, Gyroscopes, Electromyography (EMG), and Tilt sensors, Electronystagmography (ENG). Kinematic sensors (Accelerometers and Gyroscopes) are found to be the most investigated types of sensors. Also, machine learning techniques were investigated to be combined with detection algorithms.

5. Discussion and Conclusions

FSRs (foot switches) are commonly used in commercial FES walking systems such as the Odstock Stimulator, NESS L300, and the Duo-STIM. FSRs are characterised by the simplicity of their output signal which is in an on/off format. For most patients, FSRs sensors provide reliable performance, however, reliability can be affected by the position of the FSR in the shoe [1] and some gait patterns (eg: shuffling or toe walkers). The alternative is using kinematic sensors which can be placed on the shank or on the thigh of the subject, making the FES systems more cosmetic. The advantage of these sensors is that they can be used to measure joint angles making it possible to identify all gait phases. However, the output signal from this type of sensors is complex and depends on where they are worn, requiring advanced detection algorithms making them more liable to errors [2]. Moreover, reliability differs from one person to another depending on their gait pattern.

Combining different types of sensors might be a logical choice in order to compensate for the disadvantages of each sensor separately; for example, combining a FSR with a kinematic sensor as described in [2] will improve the reliability in different walking conditions and avoids detecting false events such as shifting weight from one side to another. Another approach to improve reliability in different circumstances is by integrating a machine learning technique to learn different gait patterns as suggested in [3] where a neural network was trained on gait data collected from 50 unimpaired subjects. The detection system was reported to be robust and accurate. Such system may require larger processing resources which might raise the cost and power consumption.

This comprehensive literature review has indentified that some of the sensing techniques used in FES systems are reaching maturity and offer high levels of performance and reliability. Furthermore, it is apparent that future development of FES systems will benefit from exploiting the rapid advances in machine learning techniques currently being made in fields such as robotics. Our group is currently developing adaptive systems tailored specifically to address the requirements of the next generation of FES systems.

References

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