

FES-UPP: AN ADVANCED FUNCTIONAL ELECTRICAL STIMULATION SYSTEM FOR UPPER LIMB REHABILITATION

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There are approximately 130,000 new stroke cases each year in the UK and, of those who survive, the majority find themselves having to adjust to life with reduced function in their upper limb(s). However, there is good evidence that using the impaired limb(s) to intensively practice functional movements early after stroke can lead to long term improvements in upper limb function [1]. In practice, due to the limited availability of NHS therapists, patients receive much less therapy than the evidence suggests is needed; less than 5 hours of physiotherapy contact time over the course of an inpatient stay is typical, with much of that time focused on restoring posture, balance and walking [2]. Therefore there is an important need to increase arm and hand therapy without increasing the burden on therapists.

Functional Electrical Stimulation (FES) is the application of small electrical pulses to nerves in order to generate muscle contractions, controlled in such a way as to support a patient to achieve functional tasks. It is a low cost technology and could enable stroke physiotherapists to look after several patients simultaneously. However, commercial FES systems are too inflexible and insufficiently automated to support challenging, engaging and task-focused practice. To address this problem, the University of Salford and Odstock Medical have developed a novel FES system, FES-UPP [3-6], which allows physiotherapists to quickly and easily set up FES controllers which are specific to both a particular task and to a patient's pattern of upper limb impairment. Once set up, the patient can practice the tasks with much-reduced support from their therapist. FES-UPP also provides information to the clinician and/or patient on their performance both during and after practice.

The FES-UPP system consists of a 5 channel stimulator running an FES finite state machine (FSM) controller, the FES-UPP software running on a tablet PC [3, 4], movement sensors and an instrumented object. The FES FSM-controller represents a functional task as a sequence of movement phases, each of which is associated with stimulation to one or more muscles. Progression between each of the movement phases is governed by a user-defined rule, which may use inputs from body-worn sensors, the instrumented object, a button, or time since entering the phase. The FES-UPP software guides the physiotherapist through the process of specifying the FSM for a given patient and task. In addition, it also provides data on task performance for feedback to the patient and clinician.

The author has worked on this project for both his PhD and subsequent postdoctoral research. His contributions include the design of the FSM controller [5], novel approaches to using inertial sensors for upper-limb FES control [6], and the design and implementation of the FES-UPP software. The FES-UPP system has recently received MHRA approval for a clinical investigation, which is due to start in November. The team plan to CE mark the system prior to commercial exploitation in 2017.

1. Krakauer, J.W., et al. *Neurorehabil Neural Repair*, 2012. **26**(8): 923-31; **2.** McHugh, G. al. *Disabil Rehabil*. 2014. 36(11): 925-931; **3.** Sun, M., 2014, PhD thesis, University of Salford; **4.** Smith, C., 2015, PhD thesis, University of Salford. **5.** Sun, M, et al. *A flexible finite state controller for upper limb functional electrical stimulation*. *IFESS*. 2016; **6.** Sun, M., et al. *Med Eng Phys*, 2016. 38(11): 1244-50.

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