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## **A Flexible Control System of Functional Electrical Stimulation (FES) for Upper Limb Rehabilitation**

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**Background.** Highly intensive FES-supported practice of functional tasks, under voluntary control, is showing promise to promote recovery of upper limb function following stroke [2, 3]. However, the ability to deliver this type of therapy in clinical settings is limited by available tools [1, 4]. Development of flexible systems, which support the user in the creation of task and patient-specific FES controllers has received relatively limited attention [8]. In this study, a flexible FES controller and associated graphical user interface is described, which allow therapists to set up FES controllers specific to both task and patient-specific impairment patterns. The graphical user interface (GUI) has been designed to be used by therapists with little or no programming skills.

**Methods.** A FSM controller is usually composed of a set of states, input signals, output functions, and state transition conditions [7]. In this particular case, each “state” corresponds to one movement phase and the state’s “output functions” implements the ramping of muscle stimulation(s) towards their respective targets (note the target may be zero) and then holding them at those targets. The set of possible “input signals” for the FSM controller are button status, clock time and angle data for different body segments (e.g. upper arm, forearm) via accelerometer units attached to them [6]. The “state transition conditions” implement the conditions for exiting each movement phase. Each of the parameters listed above are defined by the therapist, depending on the chosen task and the patient’s pattern of impairment, using the setup GUI.

Following ethical approvals, 12 participants (mean age = 67.25, range 41 – 88; mean years since diagnosis 5, range from 1 week – 28 years; mean Fugl-Meyer Upper Extremity score = 36.5, range from 8 - 65) with upper limb impairments following stroke were recruited to test this system in either laboratory (lab) or in two hospital settings [5]. In total, seven different functional tasks, tailored to suit the impairment levels of the particular patients were used across the study. Therapists setup the state machines using the GUI, and the controllers were either created from scratch or were pre-existing state machines, adapted to suit each patient. The seven tasks were “Sweeping coins into contralateral hand”, “Pushing up from

chair”, “Placing block on shelf” and “Picking up tray”, “Picking up mobile phone”, “Pouring from bottle to glass” and “Opening door”.

**Results.** All participants successfully completed at least one task. On average 2.75 different functional tasks (range 1 - 6) were used for each recruited stroke patient.

**Conclusion.** The testing demonstrated that the FSM FES controller could be set up by therapists with a range of patients, practicing a range of practical tasks. Further work to improve the usability and functionality of the software is ongoing in an NIHR-funded study.

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