

Lana Popović-Maneski , “MAGNETRODE: magnetic multi-pad electrode for FET” , *Proceedings of IFESS*, Toronto, Canada, June 2019, Toronto : IFESS, 2019.

MAGNETRODE: magnetic multi-pad electrode for FET

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Abstract: Use of functional electrical therapy (FET) for the grasping has bottlenecks including difficulties in positioning of the electrodes and setting the stimulation parameters. We developed a multi-pad electrode, MAGNETRODE, which allows intuitive and fast positioning with no need for demultiplexers, sensors, garments and automatic algorithms and comes in any shape and number of pads. When MAGNETRODE is combined with a multi-pad stimulator MOTIMOVE it minimizes the said limitations and provides an easy to use interface for effective FET.

Keywords: FET, FES, multi-pad electrode, stroke, grasping

Introduction

Functional electrical therapy (FET) can be used in restoration of hand functions after stroke and incomplete spinal cord lesions. It was shown that FET promotes better recovery of hand functions in subacute stroke patients compared to conventional therapy [1]. However, several bottlenecks still prevent this method to be applied as a regular treatment nowadays: difficult positioning of the electrodes, low selectivity and complicated setup of stimulation parameters. Positioning is facilitated by using multi-pad electrodes and demultiplexer which allows routing of the current pulses from the stimulator to the desired pads on the electrode. The user chooses on a PC or a tablet which pads to activate (Figure 1). There are two problems with this approach: a) the user needs to visually compare positions of the pads in user interface on PC or tablet with actual positions on the forearm, and b) as more than one active pad is required for hand opening or closing and each pad requires different current intensity, setup of parameters becomes complicated and time consuming.



Figure 1: Garment with multi-pad electrodes and demultiplexer and PC user interface, FES-a (Tecnalia Research & Innovation)

Several research groups developed automatic algorithms to detect optimal active pad positions and stimulation intensities based on feedback from sensors mounted on the hand [2-6] but in practice none of them performs good enough to be used on daily basis. This is why we propose the use of multi-pad electrodes for FET of the hand with the design as described below.

Methods

Our electrode (MAGNETRODE) is composed of silicon sponge base material and integrates 24 metal pads (Figure 2). On the side touching the skin metal pads are in contact with a layer of hydrogel (Axelgaard Manufacturing Co, Denmark) perforated in such way to reduce conductivity between neighboring pads. On the top side, metal pads can be freely accessed by the special magnetic actuator composed of a rare earth magnet covered by an insulator which can be held by the user without touching the magnet. The actuator is connected to the end of the stimulator cable. When brought over one of the metal pads the magnet sticks to the pad and forms a very low impedance connection for the current pulses from the stimulator. The user can easily shift the actuator from one pad to the other and watch the resulting movements of the hand. The positioning of the actuator is based on heuristics that follows knowledge about the positions of motor points of prime joint movers.

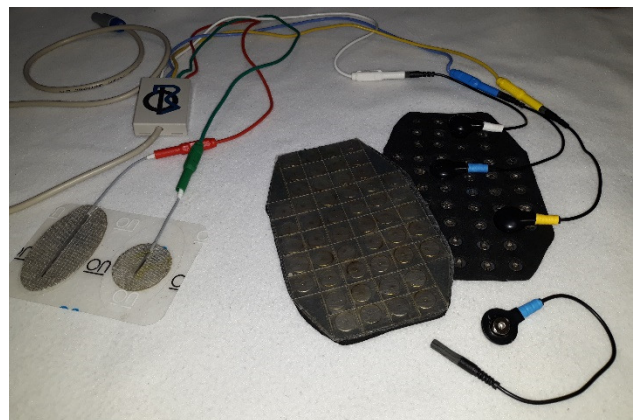


Figure 2: MAGNETRODE electrodes with activators.

MAGNETRODE was used in stroke patients with minimum or no voluntary hand opening in combination with programmable 8-channel stimulators (MOTIMOVE [7]),

3F-Fit Fabricando Faber, Serbia). The procedure for setting the positions of actuators and stimulation intensities was the following: 1) channel 1 actuator is positioned on the pad in the middle of the electrode and intensity is set over the motor threshold, 2) based on the achieved movement the actuator is heuristically moved to one of the neighboring pads until most of the fingers are moved with minimal wrist deviation, 3) while the first channel is still active the second channel activator is placed on one of the pads proximal to the fingers which did not move, 4) by trial and error the best position for second activator is found and intensity on the second channel is adjusted to meet the same excursion of fingers as with channel 1, 5) sometimes it is required to place the third channel activator to produce full hand opening; for hand closing third channel is used to stimulate the thumb thenar eminence, 6) fourth channel activator is used to find the position which produces only wrist extension or flexion – this pad is used in MOTIMOVE graphical user interface (GUI) to stabilize the wrist (e.g. low-level stimulation of wrist extension while stimulating fingers flexion for object grasping). Figure 3 shows one combination of activator positions and Figure 4 shows the stimulation profile in MOTIMOVE GUI. Profiles can be saved in program for each user.

Results

Positioning of electrodes on the skin takes less than 10s. Searching for optimal pads on dorsal and volar electrode takes 1-10min when the system is used for the first time. In subsequent applications the time needed is shorter than 1min.



Figure 3: Image of the MOTIMOVE and the MAGNETRODE with all required wiring for the FET of the grasping.

Discussion

MAGNETRODE electrode combined with MOTIMOVE stimulator provides an intuitive way of setting the optimal stimulation for hand opening and closing. There is no need for demultiplexer, automatic algorithms, sensors or garments. The electrode can be produced in any desired shape with desired number of pads. It is flexible, breathable and sticks to the skin. It can be used with any programmable stimulator with more than 4 channels (desirably 8).

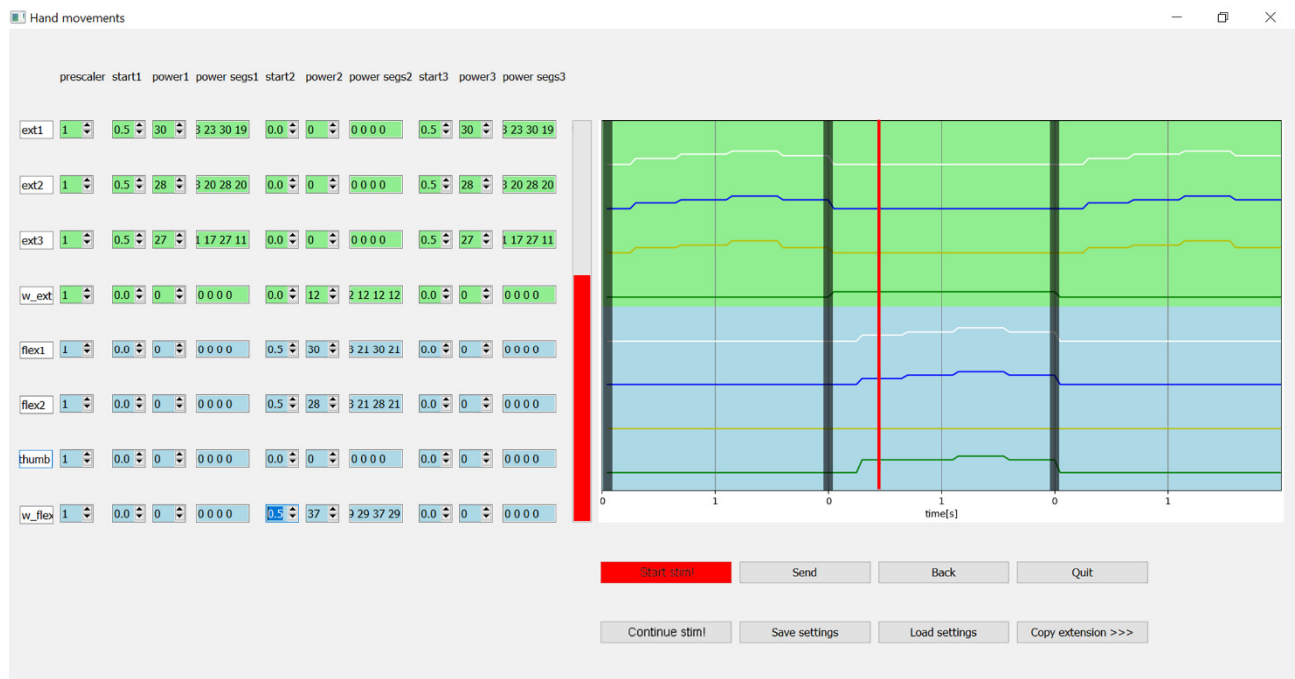


Figure 4: Stimulation profile in MOTIMOVE GUI. Green and blue backgrounds represent colors of cable connectors on the stimulator which are connected to dorsal and volar multi-pad electrode, respectively. Line colors are the same as the colors of the actuators (stimulation channels). Stimulation profile has three segments for hand opening-closing-opening. Switching

from one segment to the other can be achieved automatically after 2s or by pressing the switch in the user's hand. Last segment ends with turning off the stimulation. Vertical red line shows current position of time cursor.

Acknowledgement

The work on this project was partly supported by the grant III 44008 from the Ministry of Education, Science and Technological development of Serbia.

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