

Multi-purpose Electrostimulator Software

Nuno Costa¹, Tiago Araujo^{1,2}, Neuzá Nunes² and Hugo Gamboa^{1,2}

¹CEFITEC, Departamento de Física, FCT, Universidade Nova de Lisboa, Lisbon, Portugal

²PLUX - Wireless Biosignals S.A., Lisbon, Portugal

Keywords: Human Computer Interaction, Electrostimulation, Multi-purpose Software.

Abstract: Nowadays, most of the software for electrostimulation is made with specific purposes, and in some cases they have complicated user interfaces and large, bulky designs that deter usability and acceptability. A novel Human Computer Interaction framework was developed enabling the end user to configure and control an electrostimulator, surpassing the specific use of several electrostimulator software. In the configuration the user is able to compile different types of electrical impulses (modes) in a temporal session, and this session can be actuated in the control. To help the user in creating any type of protocol (session) we devised three standard impulse generator (rectangular, sin and triangular) and a new way of creating electrical impulses by drawing, then fitting this data and process it with a mathematical algorithm for finding simple equations to describe the data. With it, the user has the possibility to choose the best equation that fits the draw and store it mathematically structured, thus adding not only a draw editor, but also an equation editor. Therefore, we provide a tool for clinical, sports and investigation where the user is free to produce their own protocols by sequentially compile electrical impulses.

1 INTRODUCTION

In 1791, scientist Luigi Galvani showed that electricity, when applied to a frog's leg, could cause muscle twitches (Piccolino, 1998). In the intervening centuries, scientists learned much about how Electrical Stimulation or Electrostimulation (ES) affects muscle tissue and have tried to apply that knowledge to muscles paralysed by neuromuscular disease to create both therapeutic and functional effect. This field

of medicine is known variously as Electrical Muscle Stimulation or Electromyostimulation (EMS), Neuromuscular Electrical Stimulation (NMES) and Functional Electrical Stimulation (FES) electromyostimulation, consisting in nerve manipulation through electrical pulses aiming muscular contraction or sensory response for distinct applications (Malmivuo and Plonsey, 1996). Nowadays, the applications can be divided in two main areas:

- **Electrotherapy:** Rehabilitation (Von Lewinski et al., 2009); Spinal cord injury, stroke, sensory deficits, and neurological disorders (with Neural prostheses) (Cogan, 2008); and many others.
- **Physical Conditioning:** fitness; active recovery; optimizing physical performance by improvement of maximum strength of a muscle (muscular tonus) in less time (Siff, 1990).

Although ES may hold much promise there are many technical challenges that need to be surpassed. Commercial software solutions for electrostimulators grow every day, but these are often limited by a variety of factors including cost, source code inaccessibility, hardware compatibility, and more (Keller et al., 2002). Consequently, a strong tradition in scientific research is to write custom software routines. While superb for the specific tasks at hand, these

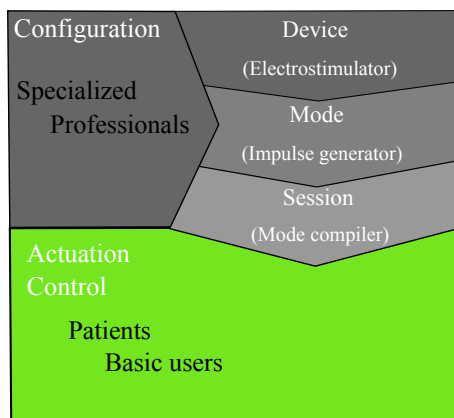


Figure 1: Generic diagram of the HCI.

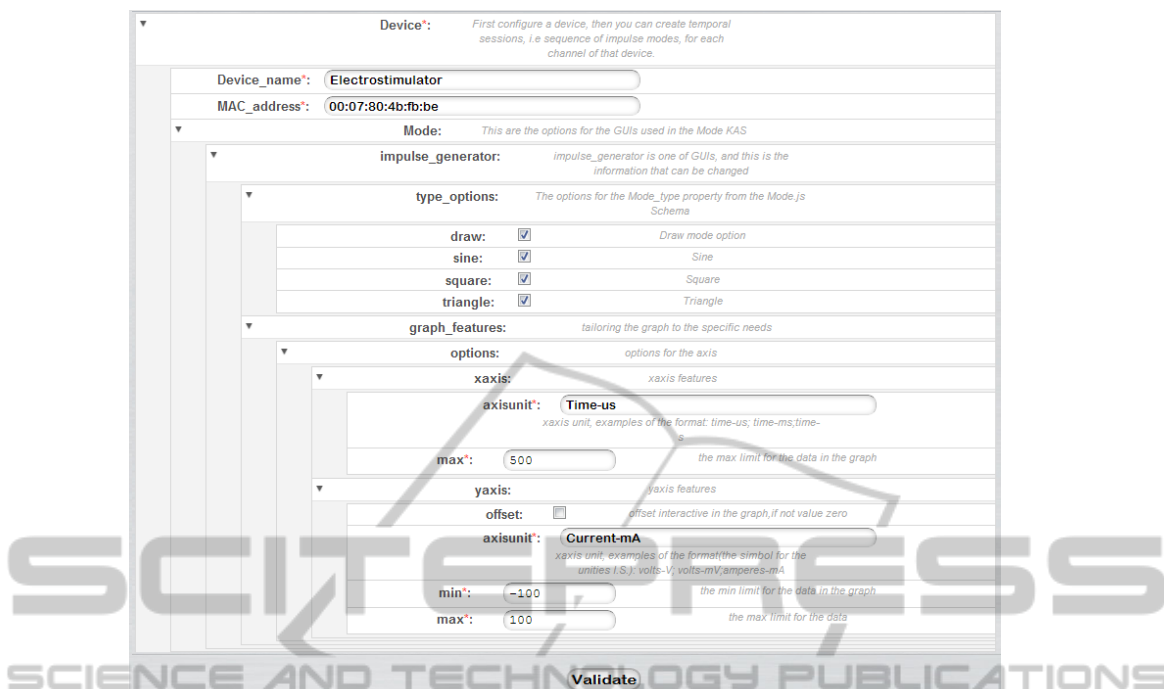


Figure 2: Device Configuration for the Electrostimulator used to test the software.

custom solutions rarely offer the flexibility and extensibility needed for them to be transferable across platforms, hardware configurations, and experimental paradigms without significant modifications. Therefore, in present time, software/hardware solutions to provide a device with a multi-purpose platform (sport, therapy or investigation), a dynamic software, which enables the user to create their own protocols, is needed (Suter et al., 2010). To contribute in solving this necessity, we created a WEB based Human Computer Interaction (HCI) that allows the user to employ the software in different types of ES applications, pursuing a non-specific software.

This paper further depicts this novel HCI based on a dynamic Knowledge Acquisition System developed previously enabling the fast re-edition of configurations if needed (Costa et al., 2012). The specific focus of this tool is to compile electrical impulses in different sessions for actuation of an electrostimulator, enabling the user to design particular types of protocols. To surpass this challenge, innovative ways of compile and create electrical impulses were implemented.

The next sections are divided in: Human Computer Interaction, a resume of the structure developed in a previous study; Configuration, a description of the methods provided to the user to compile electrical impulses; Control, a brief description of the simplicity in actuate a session.

2 HUMAN COMPUTER INTERACTION

A novel Human Computer Interaction was developed with the intention of controlling the actuation of electrical devices, like Biosignals Acquisition Systems, LEDs, motors, between others. Nevertheless, to show the potential of the tool, the biggest and the first challenge that led us to idealize it, was to control an electrostimulator for different types of applications. To demonstrate it, this article shows the capabilities of the software in controlling an electrostimulator and the contribution for Electrostimulation.

The HCI is integrated in a WEB based software for biosignals acquisition and processing from PLUX - Wireless Biosignals, S.A., enabling the control of a generic device. In this way, actuation, acquisition and processing will be possible in a closed-loop cycle.

In Biomedicine, the configuration of a device should only be performed by clinical experts, where they can adapt sessions to each patient. Overly complicated user interfaces and large, bulky designs can deter users from operate the device on a day to day basis. For example, home health care devices should have sessions previously programmed enabling the patient to only start or stop a session prepared for him, and restrict the software to this purpose because patients can't be allowed to configure or change any

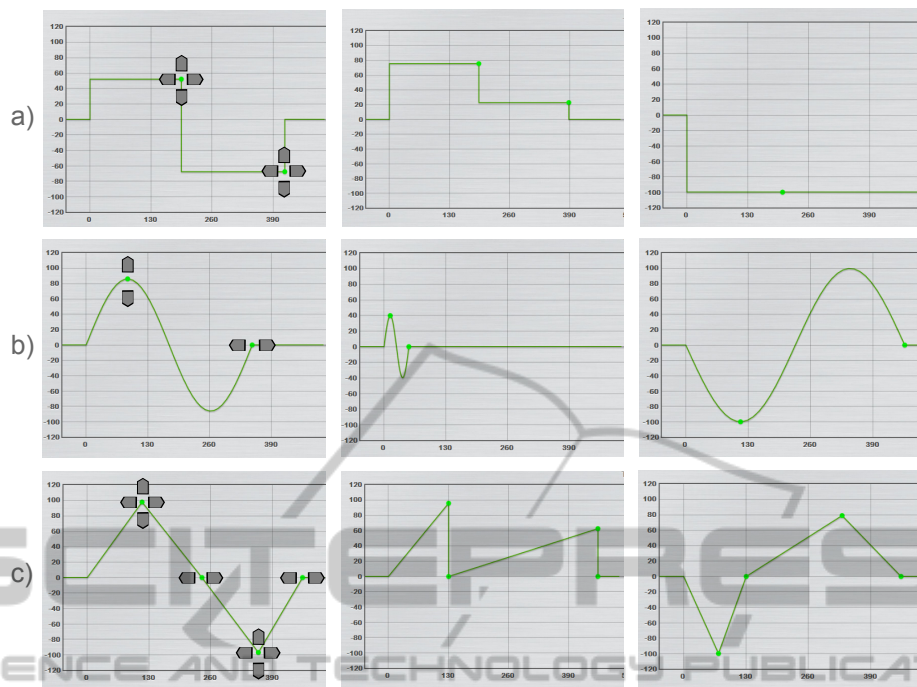


Figure 3: Example of the default impulses with the restrictions specified in the Device Configuration: a) square, b) sine and c) triangle. The arrows mark the direction in which the interactive points can be moved. In each row are presented examples of the respective impulse after moving the interactive points.

parameter in the software. Thus, to economize time, simplify interfaces, automate the device actuation and separate this tool for experts and non-experts the software was divided in Configuration and Control. Basically, as shown in Figure 1, to control we need to configure the electrostimulator, and create temporal sessions, i.e. sequence of impulse modes, for each channel of that device. Consequently, the configuration is hierarchically structured in device, mode and session. In the control we only need to choose the device and connect to it, if connected chose the session to setup the hardware, then start the session. The stop can be manual or automatic (end of the session).

3 CONFIGURATION

3.1 Device Requisites

In the case of an electrostimulator, some specific options need to be satisfied. The specifications for the potentials and limits of ES is dependent of the application and the electrostimulator. The requisites of the electrostimulator we used for this project, are: MAC Address, "00:07:80:4b:fb:be"; Pulse amplitude, 0-100 mA (1 mA step); Pulse Width, 0-500 μ s (5 μ s step); Pulse frequency, 1-200 Hz (1 Hz step); Number

of channels, 2; Number of modes, 4; Waveform type, Rectangular, triangular, sinusoidal, customized waveform (constant potential with no offset). In this way, Figure 2 represents the Device Configuration with the above requirements.

3.2 Mode

After the specification of the device requisites the user can project a new mode for a specific device. The mode permits four types of impulse configuration: square, rectangular pulse that can be changed within the data limits; sine, sin pulse that can be changed within the data limits; triangle, triangular pulse that can be changed within the data limits; draw, a novel and innovative impulse generator. The user is also able to choose the frequency (impulse per second) by moving a slider.

In the three default types square, sine and triangle, the user have to click and pull the interactive points. Examples of the three types are shown in Figure 3, each row represents an example of the respective impulse after moving the interactive points. These types allow the end user to create a lot of different impulses, but to be able of creating any type we had to devise a new form of impulse generation, the draw method.

In this new type, the user has the possibility to

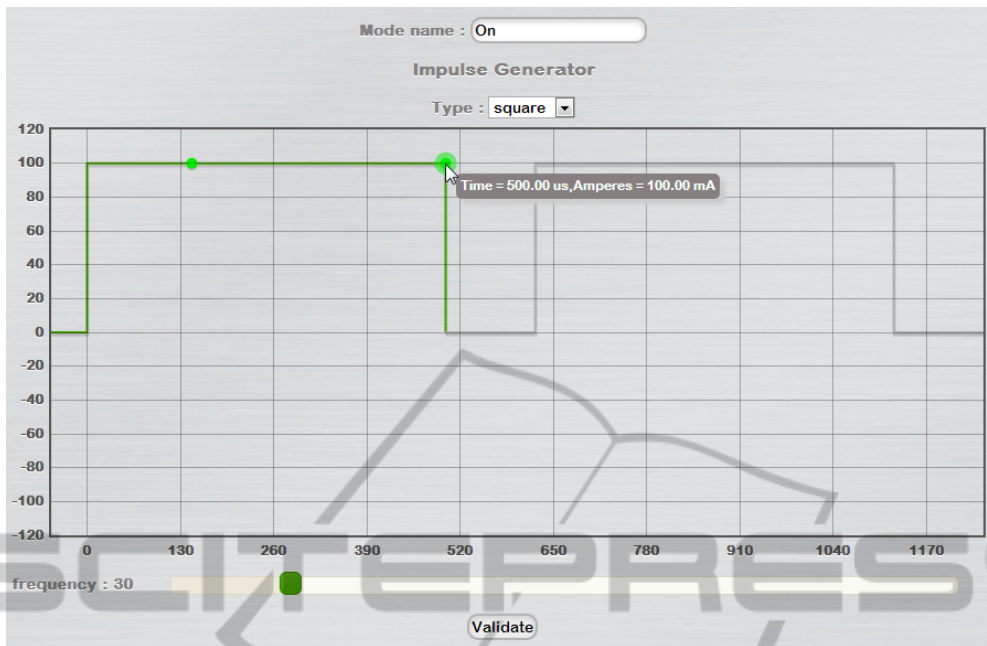


Figure 4: Configuration of the mode "On" for the Electrostimulator. Initial version of the software.

draw an impulse within the data limits, from this draw we retrieve 100 points that will be processed by an algorithm. The idea behind this algorithm it is to search within the 100 points that seem connected to each other, then propose a series of simple equations to describe the links. The best are selected, tweaked, and again tested against the data. Next, the algorithm repeats the cycle over and over, until it finds equations that have a good probability of modulate the data. Then, by choosing one of the equations, the user can see a graph with 100 points based in the equation and compare it to the drawing. If it fits the user objectives, save the equation, if not, the user can tweak the equation manually, and see the effects, or just save the 100 points from the draw. This algorithm will have large benefits when finished, because it provides a mechanism of storing the draw data mathematically structured, in this way, the user will have the possibility of re-editing the data by changing some parameters in the stored equations. So, instead of just providing a draw method to create impulses, an equation method is also available, with great relevance by simplifying the impulse generation when the impulse can be described by an equation and only few parameters need to be changed.

This algorithm is still in the initial stage and is based in the work of Schmidt and Lipson, the Eureka, a highly praised symbolic regression program (Stoutemyer, 2012).

In Figure 4 is possible to view an example of how a mode can be configured within the data limits for x

axis 0 - 500 μ s and for y axis -100 - 100 mA . The figure shows the creation of "On" mode for the electrostimulator, a rectangular pulse with 500 μ s, amplitude 100 mA, and 20 Hz of pulse frequency, i.e. 20 pulses per second.

3.3 Session

The user can create a new session for a specific device. A session is a sequence of modes, and each channel of a device can have one session programmed. A device has a maximum number of programmable modes, but they can be repeated infinitely. This mechanism is very important to program stimulation protocols, automating the control. Figure 5 shows an example of session configuration. Primarily, the definition of the modes that will be used, four is the maximum that the hardware can memorize. Afterwards, the creation of a session for the channels required, in this case, only one channel is programmed with two modes: On, 300 seconds activated and, Off, during 100 seconds (Off is a pulse with 500 μ s and amplitude 0 mA). This sequence is repeated during half an hour by activating the loop for that specific session.

Additionally, we remark that each configuration presented is not static, input new fields, re-edit or delete is fast and simple due to the dynamic Knowledge Acquisition System implemented for the HCI. A very important mechanism to optimize and adapt quickly the software, especially the configuration

Figure 5: Configuration of one channel session with the modes "On" and "Off". Initial version of the software.

(Costa et al., 2012).

4 CONTROL

Control is the division for actuation and acquisition of biosignals. In here, the user first needs to choose the device, in our case the electrostimulator, and the session to program. When the device is ready, start/stop of the session is feasible. In the course of the session is possible to acquire real time biosignals and synchronize them with the session.

Figure 6 presents the Control environment, divided in Setup and Actuation. In the Setup the user picks one of the devices configured, connects using the MAC address defined in the Device Configuration, then chooses the session to program in the Hardware. If the hardware is correctly set up, start/stop and information of the session for each channel are available within the Actuation.

The control area will have many device sessions templates. Therefore, a quick approach by the user will enable the simple selection of a pre-defined session and start the actuation immediately.

5 CONCLUSIONS

A strong tradition in neurophysiology research is to write custom software routines. These software are

specific and rarely offer the flexibility and extensibility needed for them to be transferable across platforms, hardware configurations, and experimental paradigms without significant modifications. Also, most of the times these software have confuse, large and bulky interfaces that can deter users from using the software. Electrostimulation is one of the areas that suffers from these problems. For these reasons, and pursuing usability and acceptability, we are developing a HCI that has a great potential to be transferable across different types of electrical device control, and to demonstrate it, we are able to produce different types of sessions to control the actuation of an electrostimulator.

For this purpose we provide mechanisms to configure and control a device. The most important mechanisms are: the separation in Configuration and Control; Configuration, where clinical professionals can configure a device with sessions for each channel through the compilation of electric impulses; Control, where the user just needs to choose the device and session (set up the device) then simply start/stop the session prepared in the configuration; the sequence of configuration (Device, Mode, Sessions), that supplies the user with a structured configuration; the tools in Mode, enabling the end user to shape the impulses at its own desire, and with the draw, plus equation algorithm, implemented the user will be able to produce any kind of impulse and store information mathematically structured; the compilation of modes in Session allowing the creation of temporal sessions for

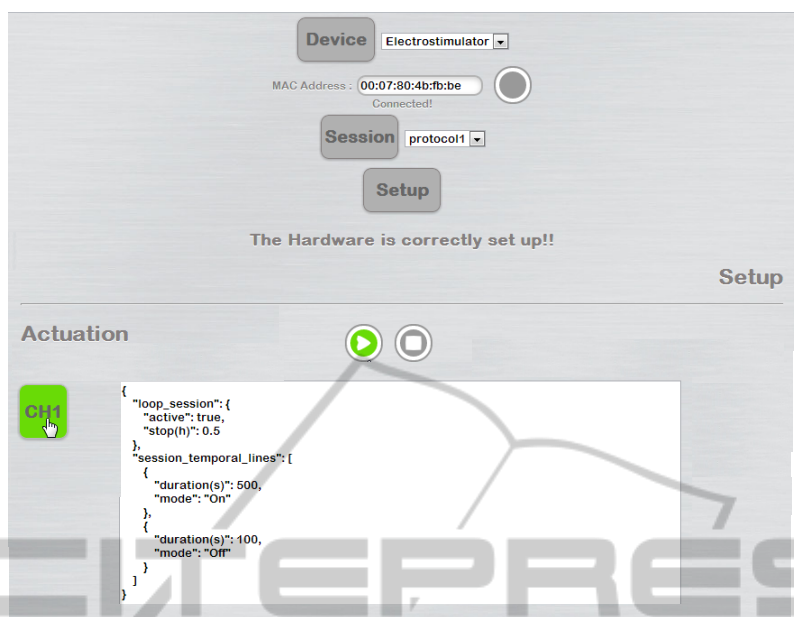


Figure 6: Control environment using the Electrostimulator defined in the configuration and session "protocol1".

the actuation of an electrostimulator, i.e. permits to program stimulation protocols. Thus, creating a dynamic, flexible way of automate the actuation of stimuli.

Depending on the stakeholder the combination Configuration-Control will change. Configuration will be enabled, disabled or will have different levels of restrictions. In the Control area different devices and sessions will be programmed by default for a fast approach by the user (setup the device then start/stop the session). Ideally, the various envisioned users should be consulted on whether they would be open to use such a software package and, if so, under what restrictions. Interviews or questionnaires will be suitable instruments for this. We hope this could be the foundation for building a business model and further develop ideas on how to penetrate the market.

We also provide a tool to generate dynamic configurations, that are fast and simple to re-edited. Therefore, if for example the configurations described in this article are not optimized to configure a specific electrostimulator we can easily optimized them.

With this powerful tool we provide a user-friendly software solution with a multi-purpose platform for sport, therapy and research.

REFERENCES

Cogan, S. (2008). Neural stimulation and recording electrodes. *Annu. Rev. Biomed. Eng.*, 10:275–309.
 Costa, N., Araújo, T., Nunes, N., and Gamboa, H. (2012).

Knowledge acquisition system based on json schema - implementation of a hci for actuation of biosignals acquisition systems. In Cabello, E., Virvou, M., Obaidat, M. S., Caldeirinha, R. F. S., Ji, H., and Vergados, D. D., editors, *SIGMAP*, pages 255–262. SciTePress.
 Keller, T., Popovic, M., Pappas, I., and Müller, P. (2002). Transcutaneous functional electrical stimulator “complex motion”. *Artificial organs*, 26(3):219–223.
 Malmivuo, J. and Plonsey, R. (1996). *Bioelectromagnetism*, volume 34. Peter Peregrinus LTD.
 Piccolino, M. (1998). Animal electricity and the birth of electrophysiology: the legacy of luigi galvani. *Brain research bulletin*, 46(5):381–407.
 Siff, M. (1990). Applications of electrostimulation in physical conditioning: a review. *The Journal of Strength & Conditioning Research*, 4(1):20.
 Stoutemyer, D. (2012). Can the eureka symbolic regression program, computer algebra and numerical analysis help each other? *Arxiv preprint arXiv:1203.1023*.
 Suter, B. A., O’Connor, T., Iyer, V., Petreanu, L. T., Hooks, B. M., Kiritani, T., Svoboda, K., and Shepherd, G. M. G. (2010). Ephus: multipurpose data acquisition software for neuroscience experiments. *Frontiers in Neural Circuits*, 4:100.
 Von Lewinski, F., Hofer, S., Kaus, J., Merboldt, K., Rothkegel, H., Schweizer, R., Liebetanz, D., Frahm, J., and Paulus, W. (2009). Efficacy of emg-triggered electrical arm stimulation in chronic hemiparetic stroke patients. *Restorative Neurology and Neuroscience*, 27(3):189–197.