Ref. Ares(2024)2360388 - 29/03/2024

Project:

BioMeld

Grant Agreement (GA) No. 101070328

"A MODULAR FRAMEWORK FOR DESIGNING AND PRODUCING BIOHYBRID MACHINES"

Call: HORIZON-CL4-2021-DIGITAL-EMERGING-01
Type of action: Research and Innovation action (RIA)
Start date of project: 01/10/2022 Duration: 36 months

D3.5: FEEDBACK SYSTEM CONTROL SOFTWARE

DELIVERABLE FACTSHEET

Project title | Acronym | Number		A Modular Framework for Designing and Producing Biohybrid Machines | BioMeld | 101070328	
Due Date:	31/03/2024	**Date of submission:**	29/03/2024
Month of Project	18	**Month of submission:**	18
Title of deliverable:	D3.5 – Feedback System Control Software	**Work Package:**	WP3 – Manufacturing modular, adaptable, reconfigurable BHM catheter
Dissemination level:	PU	**Version/Status**	V1 – M18
Deliverable leader (Name|Organisation)	UniCA	**Editor(s)**	Stefano Lai
Contribution of partners	UniCA wrote the deliverable. IBEC provided feedback on the software. UNSPF commented the final version.		
Final review and approval	UNICA, IBEC, UNSPF		
Keywords	Software, Matlab, control		
Abstract	We developed control software enabling real-time data communication, storage, and visualization. For communication with the electronic module we employed a Bluetooth protocol. The software was developed using Matlab2021b. The interface consists of three different control windows for (i) the management of the main stimulation parameters, (ii) implementation of advanced stimulation algorithms, and (iii) searching for the minimum stimulation parameters to induce contraction in the tissues.		
Document change history			

Date	Authors	Description
21/03/2024	UNICA	First draft delivered to coordinator
23/03/2024	UNICA	Final version delivered to coordinator

CONSORTIUM

	Name	Short Name	Country
1.	UNIVERZITET U NOVOM SADU, POLJOPRIVREDNI FAKULTET NOVI SAD	UNSPF	Serbia
2.	SCUOLA SUPERIORE DI STUDI UNIVERSITARI E DI PERFEZIONAMENTO S ANNA	SSSA	Italy
3.	FUNDACIO INSTITUT DE BIOENGINYERIA DE CATALUNYA	IBEC-CERCA	Spain
4.	SMART SENSING S.R.L.	SMART SENSING	Italy
5.	UNIVERSITA DEGLI STUDI DI CAGLIARI	UNICA	Italy
6.	LEVERETTE LANCE	Lance Leverette	Belgium
7.	The University of the West of England	UWE Bristol	United Kingdom

EXECUTIVE SUMMARY

We developed control software as a Matlab 2021b-based application enabling real-time data communication, storage, and visualization. The interface consists of three different control windows described in Section 2. Main tab window has been designed to allow the user to control all the main stimulation parameters and its features are described in Section 2.1. Modulation tab window was designed to allow the user to perform advanced tests for the control of the bioactuator, through modulation of electrical stimulation and its features are described in Section 2.2. Threshold tab window was designed to allow the researcher to conduct in-depth and detailed research on the current levels necessary to contract the bioactuator statistically, and its main features are described in Section 2.3. Contribution of involved partners is described in Section 3, while conclusions are outlined in Section 4.

LEGAL NOTICE
This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement number 101070328.
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1 DESCRIPTION OF TASK

The control software will be developed as a standalone application using standard development libraries, enabling real-time data communication, storage, and visualization, and aimed to be solid, unified, and modular. A Bluetooth protocol will be employed for communication with the electronic module. The software will include calibration curve and, possibly, algorithms for further data processing. User-friendly data visualization and electronic module control will be ensured. The layout will be adapted according to the direct feedback provided by users during the employment of the system.

2 DESCRIPTION OF WORK AND MAIN ACHIEVEMENTS

Control of the electrical stimulator and generation of embedding patterns is performed using a graphical interface developed using Matlab 2021b. The interface developed using App Designer will be released as a free standalone application.

The interface consists of three different control windows that allow the management of the main stimulation parameters, implementation of advanced stimulation algorithms, and searching for the minimum stimulation parameters to induce contraction in the tissues.

The different features of the developed interface will be presented below.

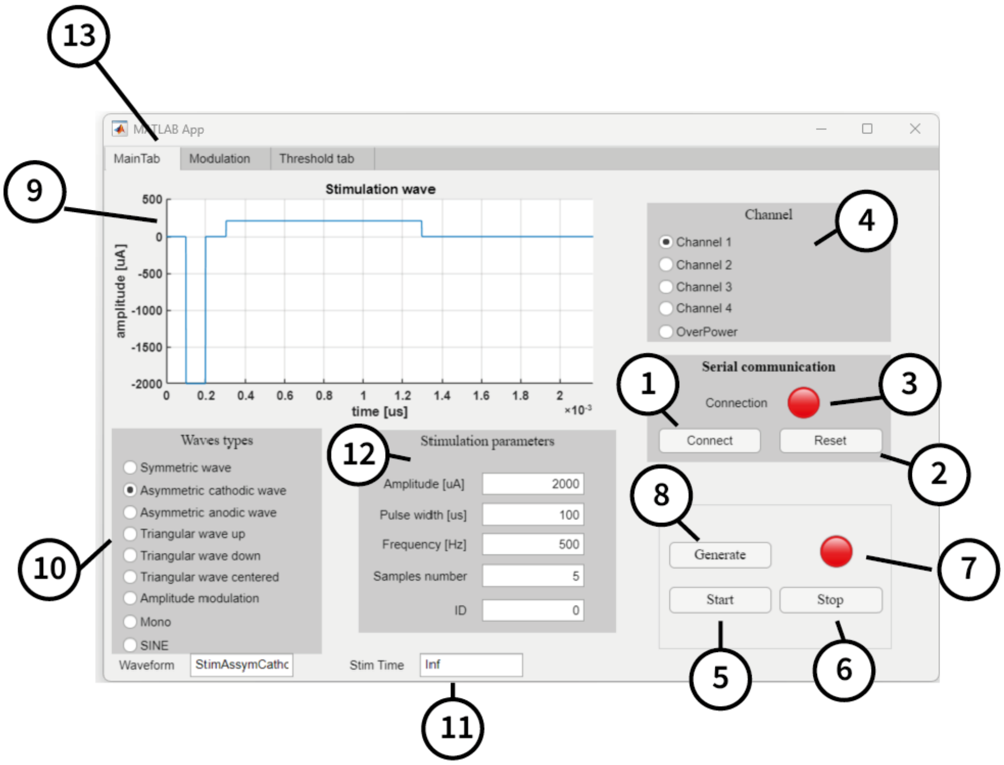

Figure 1 Main Tab Window view.

2.1 MAIN TAB WINDOW

The Main Tab Window is shown in Figure 1. The Main Tab Window has been designed to allow the user to control all the main stimulation parameters. The main features of the window are explained below

2.1.1 **Connect Button**: The button allows the user to establish the connection with the stimulator and to initialize the Bluetooth communication.

2.1.2 **RESET Button**: The button allows the user to close communication with the stimulator and reset the channel and settings.

2.1.3 **Connection LED**: The LED is used to show the user the status of the connection between the stimulator and the interface. The red LED indicates an absent connection, while the green LED indicates the presence of an active connection.

2.1.4 **Channel selection box**: This selection box chooses the stimulation channel. The user can choose whether to stimulate via one of the four channels on the stimulator ("Channel 1", "Channel 2", "Channel 3", "Channel 4") or whether to combine the currents of the channels into a single stimulation channel ("OverPower").

2.1.5 **Start Button**: The start button allows the user to start a stimulation session with the selected parameters.

2. 1.6 **STOP Button**: The stop button allows the user to stop stimulation.

2. 1.7 **STIMULATION LED**: The LED shows the user the stimulation status. The red LED indicates the absence of stimulation in progress, while the green LED indicates the presence of active stimulation.

2. 1.8 **Generate Button**: The button allows the user to plot the type of waveform selected in the chart (9), thus giving the user a graphic representation of the stimulus.

1.9 **Waveform Plot**: Graph of the selected waveform. The graph represents the selected stimulus in terms of current and duration.

2. 1.10 **Waveform selector**: stimulation waveform selector. The user can select between:

i. "Symmetric": Biphasic symmetric waveform.

ii. "Asymmetric cathodic": Biphasic asymmetric cathodic first stimulation waveform.

iii. "Triangular up": Biphasic Linear ramp with increasing amplitude waveform.

iv. "Triangular down": Biphasic Linear ramp with decreasing amplitude waveform.

v. "Triangular centered": biphasic triangular centered waveform.

vi. "Amplitude modulation": Sequence of 10 biphasic asymmetric stimuli with increasing current.

vii. "Mono": monophasic waveform.

viii. "SINE": sinusoidal waveform.

2. 1.11 **Stimulation Time selector**: stimulation duration selector. The user can set a timer that regulates the duration of the stimulus. The user can set a value in seconds for the timer by entering a number greater than "1" or turn off the timer by entering "Inf". If the timer is disabled, the end of stimulation is obtained only by using the Stop button (6).

2. 1.12 **Stimulation Parameters' box**: The user can set the following stimulation parameters:

i. Current ("Amplitude"): maximum stimulation current in uA. In the case of an asymmetric wave, the amplitude is the stimulation current of the phase with the highest current. The user can enter a current between 100uA and 18000uA.

ii. Duration ("Pulse width"): duration of the anodic (or cathodic) phase of the stimulation in us. In the case of an asymmetric wave, the PW is the stimulation period of the phase with the highest current. The user can enter a value between 100us and 50000us.

iii. Frequency ("Frequency"): stimulation frequency in Hz. The user can enter a value between 1Hz and 500Hz.

iv. Samples number: number of samples used in generating the triangular waveforms.

2. 1.13 **Window selector**: The interface is equipped with three different windows. The window in question is called "MainTab". The user can also select the "Modulation" and "Threshold tab" windows.

2.2 MODULATION TAB WINDOW

The Modulation Tab Window is shown in Figure 2. The Modulation Tab Window was designed to allow the user to perform advanced tests for the control of the bioactuator, through modulation of electrical stimulation. The main features of the window are explained below

Figure 2 Modulation Tab Window view.

2.2.1 **Start Button**: The start button allows the user to start a stimulation session with the selected parameters.

2.2.2 **STOP Button**: The stop button allows the user to stop the stimulation.

2.2.3 **Modulation Box:** The Modulation Box allows the user to select and enable the stimulation modulation mode he prefers between *amplitude modulation*, *pulse width modulation* and *frequency modulation*. Modulation can be carried out with linear or step increases by selecting the "STEPS" parameter.

2.2.4 **Modulation Steps:** Index that selects the number of steps to perform during modulation

2.2.5 **Modulation Duration**: Index that selects the duration of each stimulation step.

2.2.6 **Plot Button Plot**: The button allows the user to plot the behavior of the selected modulation in the chart (2.2.7).

2.2.7 **Waveform Plot**: Graph of the selected stimulation pattern. The graph represents the variation of stimulation parameters during the modulation.

2.2.8 **Amplitude modulation parameters:** The user can select the minimum and maximum amplitude during amplitude modulation. The minimum stimulation amplitude is selected using "Amin," while the maximum is selected using "Amax". In non-amplitude modulation mode, "Amin" sets the amplitude to use.

2.2.9 **Pulse width modulation parameters:** The user can select the minimum and maximum pulse width during pulse width modulation. The minimum stimulation pulse width is selected using "PWmin," while the maximum is selected using "PWmax". In non-PWmodulation mode, "PWmin" sets the pulse width to use.

2.2.10 **Frequency modulation parameters:** The user can select the minimum and maximum frequency during frequency modulation. The minimum stimulation frequency is selected using "Fmin," while the maximum is selected using "Fmax". In non-frequency modulation mode, "Fmin" sets the frequency to use.

2.2.11 **STIMULATION LED**: The LED shows the user the stimulation status. The red LED indicates the absence of stimulation in progress, while the green LED indicates the presence of active stimulation.

2.3 THRESHOLD TAB WINDOW

The Threshold Tab Window is shown in Figure 3. The Threshold Tab Window was designed to allow the researcher to conduct in-depth and detailed research on the current levels necessary to contract the bioactuator statistically. The search for the stimulation threshold occurs by collecting the stimulation amplitudes that lead to muscle activation, which are averaged to obtain the statistical threshold. The main features of the window are explained below.

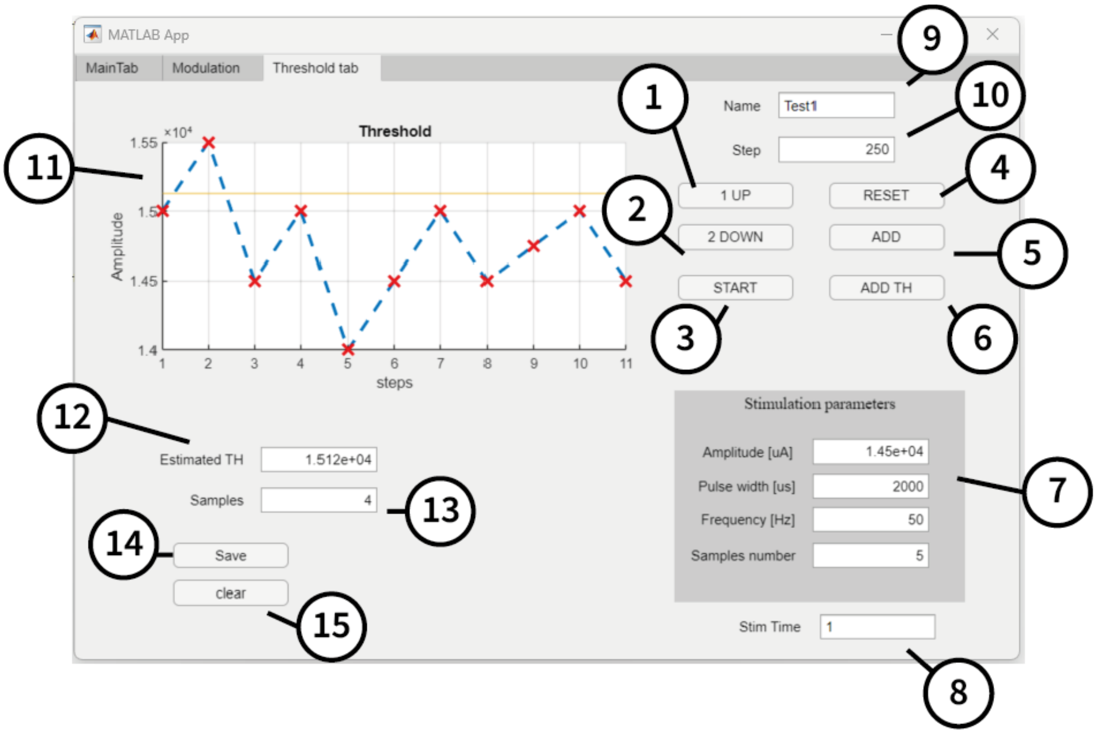

Figure 3 Threshold Tab Window view.

2.3.1 **1Up button**: The button is used by the user to increase the inclusion width by an indicator quantity from STEP (2.3.10);
2.3.2 **2Down butt**on: The button is used by the user to decrease the adhesion width by an amount equal to twice the value indicated by STEP (2.3.10);

2.3.3 **START**: The button allows the user to start the connection;
2.3.4 **RESET**: The button lets the user delete the data collected during the threshold estimation.
2.3.5 **ADD**: the button adds the current presentation point to the plot (2.3.11);
2.3.6 **ADD TH**: the button saves the value of the estimated threshold for the arrival PW;
2.3.7 **Stimulation parameters box**: the box allows the user to select the different presentation parameters in terms of amplitude, duration, frequency, and samples used for the formation of the electrical stimulus;
2.3.8 **Stimulation time**: the parameter allows the user to generate sequences of duration indicated by the parameter;
2.3.9 **Test Name**: The user can give a name to the test performed. The name will then be used when saving the data.
2.3.10 **STEP**: The value of the participation variation steps is attributed by assigning a step value.
2.3.11 **Threshold plot**: The graph shows the estimate of the launch threshold carried out during the test;
2.3.12 **Estimated TH**: The estimated threshold is reported automatically. The threshold is estimated as the average of the thresholds identified by the user over the number of repetitions;
2.3.13 **Samples**: Indicates the number of repetitions performed when estimating the delivery threshold.
2.3.14 **Save**: The button allows you to save a Matlab structure containing the tests' results.
2.3.15 **Clear button**: The clear button deletes the data in the interface.

3 CONTRIBUTION OF INVOLVED PARTNERS

The software interface was created through a solid and intense exchange of ideas between UNICA and IBEC in order to make software available that is user-friendly and, at the same time, guarantees the broadest possible programmability.

The interface is equipped with multiple selectors of stimulation forms and allows the user to investigate different stimulation durations and amplitudes, as requested by IBEC.

4 CONCLUSIONS

A developed graphical interface for controlling diffusion parameters based on Matlab 2021b was developed. The interface presents three different windows to allow the user to select the penetration parameters in terms of waveform, duration, frequency, amplitude, and type of algorithm, as well as will enable the investigation of the depth threshold necessary to induce the activation of the bioactuator.