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1 author:

Oana Andreea Rusanu
Transylvania University of Brașov

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LabVIEW Instruments for Creating Brain-Computer Interface Applications by Simulating Graphical Animations and Sending Text Messages to Virtual and Physical LEDs Based Display Systems Connected to Arduino Board

O A Rușanu[1]

[1]Product Design, Mechatronics and Environment Department, *Transilvania* University of Brașov, Brașov, Romania

E-mail: oana.rusanu@unitbv.ro

Abstract. The brain-computer interface (BCI) is a multidisciplinary research field aimed at helping people with neuromotor disabilities. A BCI system enables the control of mechatronic devices by using cognitive intentions translated into electroencephalographic signals. This paper presents the implementation of LabVIEW-based display systems that can be controlled by a brain-computer interface based on detecting the voluntary eye blinks used as commands. The interactive virtual or physical display systems are helpful thanks to running or simulating various graphical animations or transmitting different text messages in a user-customizable way. The proposed LabVIEW-based virtual display systems provide versatile functionalities such as: customizing the own visual animations and the movement of any text message by switching the direction (to the left or to the right) depending on the user's choice. This paper presents five original virtual LEDs based display systems developed in LabVIEW graphical programming environment. The implemented LabVIEW applications included: an 8x8 LEDs matrix for simulating graphical animations, 2x16 LCD TEXT for showing text messages, and a 7-segments display for implementing chronometer functionality. Moreover, the LabVIEW virtual display systems were interfaced with the physical display systems (8x8 LEDs matrix controlled by MAX7219 driver and 2x16 LCD TEXT) connected to the Arduino Uno board.

1. Introduction

The brain-computer interface (BCI) is a multidisciplinary research field aimed at helping people with neuromotor disabilities suffering from tetraplegia or paralysis caused by neurological diseases such as amyotrophic lateral sclerosis and Locked-In syndrome, severe injuries to the spinal cord, or cerebral stroke. The BCI technology bypasses the normal pathway starting from the motor cortex, crossing the spinal cord, and ending with the effectors (muscles). At the current moment, even though they are still expensive and need some experience to set up, configure and use to customize a BCI assistive application, the biomedical engineering companies deliver portable headsets able to acquire the electroencephalographic (EEG) signals. Therefore, the researchers and the developers should bring novel insights towards leveraging the advanced functionalities provided by the portable EEG headsets and integrating them into novel brain-computer interface applications necessary to improve the life of the neuromotor disabled people.

The display systems are spread everywhere around different professional, scientific, educational, and entertainment areas to show interactive texts, transfer important messages, and exchange information for advertising, communication, and safety. Therefore, several medical centers (dental clinics, pharmacies, health care houses), commercial centers (shops, supermarkets, malls), or entertainment centers (providing digital games, music, and dance) need attractive advertisements with appealing graphical animations and shiny messages shown on LEDs based interactive display systems.

Otherwise, scientific research areas such as brain-computer interface involve experimental paradigms based on virtual or physical display systems to enable the detection of evoked potentials such as P300 or SSVEPs (Steady-State Visually Evoked Potentials) triggered when the user focuses his/her attention on viewing keyboards or LEDs corresponding to specific frequencies. Moreover, the augmentative and alternative (AAC) systems facilitate communication for people with verbal disabilities by offering them the possibility to use virtual interactive display systems composed of pictures, emoticons, visual representations, or graphical animations associated with different essential activities (indicating the need for hunger, thirst, sleep, warm, cold and others) or feelings, states of mind and wishes (transmitting the happiness, sadness, angriness, fear, hopeless and others). Regarding the educational purpose, the display systems could increase the attention level by showing pupils funny LEDs based images, projecting important information or messages to LEDs based display systems, and lighting various patterns of LEDs to capture their interest and advance the learning process. One of the most frequent applications of display systems is the transfer of messages for safety reasons to inform people to be careful in different situations: not to enter a prohibited zone, not touch a dangerous area, or not interact with wild animals. Also, among the most implemented applications of display systems, it is the information transmission into different locations: bus or train stations, waiting rooms from medical institutions, and advertising messages from commercials centers.

The main aim of the current paper is to prove and develop novel, simple brain-computer interface applications involving precise and easy to achieve commands associated with the voluntary eye-blinks for controlling the LabVIEW display systems based on LEDs to run graphical animations, show text messages, and the measured time interval using the virtual Chronometer. This paper presents the development of five original LabVIEW based applications for creating virtual interactive display systems and enabling versatile functionalities: LEDs matrices for mathematical conversions between numerical systems (binary to hexadecimal and hexadecimal to binary) and simulating graphical animations or visual effects, 2x16 LCD TEXT for projecting different messages that can be moved to opposite directions (both left and right) and 7-segments (8 digits) display for implementing the chronometer function. The proposed LabVIEW-based display systems are also integrated with the Arduino Uno board to synchronize graphical effects, message sending, and Chronometer running to virtual and physical displays. Therefore, digital displays (MAX7219 based 8x8 LEDs matrix and 2x16 LCD TEXT) are connected to Arduino Uno.

The developed LabVIEW interactive virtual displays could be helpful for different purposes: educational or e-learning (to enable additional remote applications necessary for studying microcontrollers related subjects), communication, entertainment, or even brain-computer interface (by the further implementation of various frequencies lighting on the LEDs matrix). The novelty of this paper resides in the development of LabVIEW-based virtual display systems for creating versatile simulations that can be integrated with Arduino and improving the scientific field of the brain-computer interface by experimenting with novel, simple and interactive applications. There is reduced scientific evidence [1-2] for integrating BCI applications with virtual display systems. Some of the BCI-related experiments involve visual stimulation (target numbers) for awareness detection in patients suffering from disorders of consciousness [3]. Also, BCI research focused on providing novel stimulation [4] by designing a virtual keyboard for generating P300 evoked biopotentials aimed at communication tasks. Across the scientific literature [5-6] including the mixture between concepts of BCI, IoT and affective computing, it is hard to identify similar software applications to develop virtual displays involving interactive and customizable functionalities according to the interest and preference of the users. The proposed LabVIEW display systems offer the users the advantage of designing their animations and creating their text messages in a straightforward, quick, and friendly way.

This paper is structured as follows: Section 1 is the Introduction, Section 2 is an overview of the previous research work on display systems, Section 3 describes the proposed five original LabVIEW applications for virtual interactive display systems and the BCI applications, and Section 4 comprises the results and discussions, and Section 5 includes the conclusions.

2. Previous Work of Development Interactive Display Systems

This section overviews the previous scientific work reported on the physical or LabVIEW-based virtual display systems. The paper [7] highlights the integration between LabVIEW and Arduino to enable traffic light control. The article [8] emphasized using the LINX library to interface LabVIEW with Arduino and Raspberry Pi and implement an LED display to send warnings about exceeded temperature or humidity in a medical warehouse. The research publications [9-10] focused on using a physical LED matrix to display any message by converting the image into a byte array. The paper [11] presented an intelligent noticing system controlled using a dot matrix display, voice, SMS, RF transceiver, and GSM modem. Also, the scientific article [12] described an innovative information display system by integrating microcontroller and GSM models. According to the paper [13], the LEDs-based display system's automatic configuration is implemented using computer vision, and the message exchange is achieved by MQTT (Message Queuing Telemetry Transport) protocol.

Beyond the scientific evidence of leveraging the strong impact of display systems in our everyday life, there are also several YouTube tutorials [14-15] and Internet resources [16-18] providing valuable knowledge and practical examples to support the implementation of LabVIEW based virtual and interactive screens composed of LEDs.

3. Implementation and Design of LEDs based Virtual Display Systems by the integration between LabVIEW and Arduino

3.1. Binary to Hexadecimal Conversion Applied to an 8x8 LEDs Matrix

This paper presents the first customized LabVIEW application (Figure 1) to execute a binary to hexadecimal conversion algorithm applied to an 8x4 or 8x8 LEDs matrix. Considering the version of the 8x8 LEDs matrix, the Front Panel includes the following elements: 8 Boolean column arrays containing 8 LEDs each for setting the binary code, 8 string indicators for displaying the hexadecimal codes, some decorations (boxes or panels), a label for the title, and the stop button. Each LED that is ON or red-colored is associated with the Boolean control set to the true value. Each LED that is OFF, or white-colored is associated with the Boolean control set to the false value. The binary code should be read starting from up to the bottom.

The structure of the Block Diagram underlying the first presented LabVIEW application can be entirely checked in the video clip uploaded to YouTube [19-21]. The Block Diagram has a compact structure, including a while loop, the input data (8 Boolean arrays with 8 LEDs each), 8 subVIs, and 8 output data (8 string indicators). The subVI comprises two phases: firstly, the implementation of a conversion algorithm between binary and decimal numerical systems, and secondly, the calling of a function to enable the conversion between decimal and hexadecimal numerical systems.

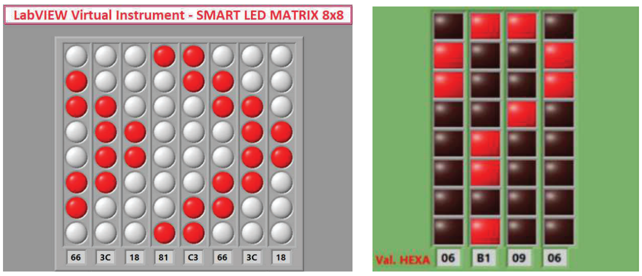

Figure 1. The Front Panel (The Graphical User Interface) of the first LabVIEW Application that enabled the Binary to Hexadecimal Conversion Algorithm Applied to an 8x8 / 8x4 LEDs Matrix.

3.2. Hexadecimal to Binary Conversion Algorithm for Creating and Running Graphical Effects Displayed to an 8x8 LEDs Matrix

This paper presents the second customized LabVIEW application (Figure 2), enabling the conversion of the hexadecimal values to the binary codes. The hexadecimal values, returned as output data from the previously described LabVIEW application, should be grouped into rows of 4 or 8 elements each and stored in .csv files. Every .csv file, composed of many rows, is associated with a graphical effect or a visual animation. Each row, including 4 or 8 hexadecimal values, constitutes a single frame of a specific graphical effect. This LabVIEW application has two running modes: manual and automatic. In the manual running mode, the user needs to increase/decrease the number of frames displayed on the 8x4 or 8x8 LED matrix for an indefinite time interval. At the same time, the hexadecimal values of the current animated frame are also shown. The user only needs to select the desired graphical effect in the automatic running mode and adjust the corresponding frames' speed. Therefore, all the frames contained by the graphical effect are entirely and continuously displayed on the 8x4 or 8x8 LED matrix. The user sets the transition time interval between displaying each frame during the automatic running mode of the LabVIEW application.

The Front Panel or the user interface includes several further described elements. A 2D array of string values displays the hexadecimal values read from the .csv files. Two 2D arrays of Boolean values that generate the 8x4 or 8x8 LEDs matrix are necessary to display the animated frames in manual and automatic running modes. A combo box from the String Palette enables the selection of the desired graphical effect. Two 1D arrays of String values are necessary for the manual and automatic running modes to display each row of hexadecimal values that is read from the .csv file and associated with a single animated frame. A Boolean push button allows switching between running modes: manual or automatic. A Meter numerical control is used to increase or decrease the transition speed of the animated frames. A Stop button closes the LabVIEW application. Different decorations include elements or panels, and a label displays the title of the LabVIEW virtual instrument.

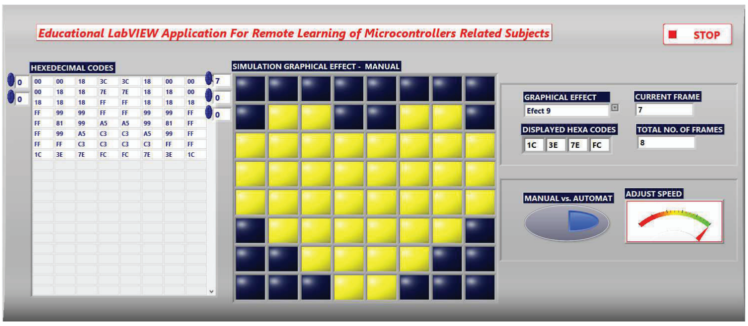

Figure 2. The Front Panel (The Graphical User Interface) of the second LabVIEW Application that enabled the Hexadecimal to Binary Conversion Algorithm Applied to an 8x8 LEDs Matrix.

3.3. Simple Design and Automatic Running of Graphical Effects to both a Virtual and a Real 8x8 LEDs Matrix Connected to Arduino Uno

This paper presents the third customized LabVIEW application (Figure 3), allowing the user to create the desired graphical effect composed of a maximum of 8 frames by simply turning on and off the LEDs (Boolean controls) included in the 8x8 virtual matrix. Therefore, the advantage of this software instrument is the versatile functionality enabling the user to customize and change the animation patterns directly in the Front Panel at any moment during the running mode of the LabVIEW application. Moreover, this virtual instrument offers two running modes: the manual mode for designing the animated frames and the automatic mode for running the graphical effect by transitioning across the customized patterns with a user-adjustable speed. The Front Panel of the LabVIEW instrument is comprised of a container – Tab Control – including five windows for providing the possibility of creating and running five different graphical effects with eight frames each. Likewise, according to Figure 4, the fifth window displays the hexadecimal codes corresponding to each of the eight frames of the fifth graphical effect. The hexadecimal codes could be further used by a script written in C programming language to enable the running of the graphical effect displayed on a real LED matrix connected to the Arduino board. Otherwise, the current LabVIEW application proved the possibility of parallel displaying the customized animations in the virtual environment and the physical MAX 7219 driver-based 8x8 LED matrix connected to the Arduino Uno board.

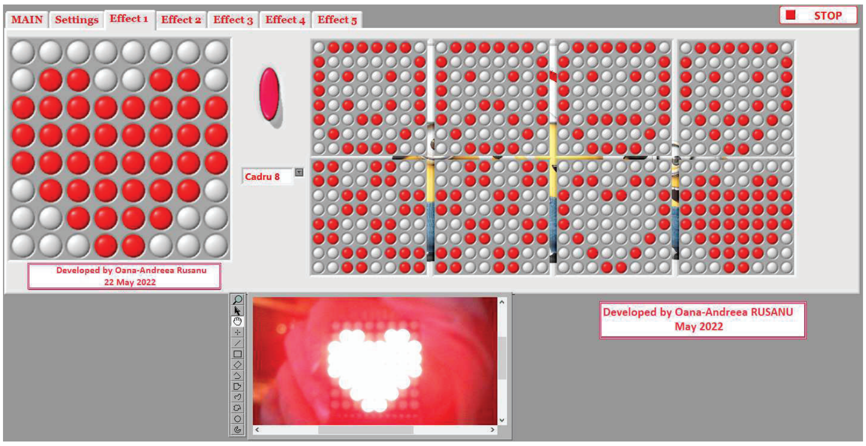

Figure 3. The Front Panel (The Graphical User Interface) of the third LabVIEW Application that enabled the Automatic Running of Graphical Effects Displayed to 8x8 LEDs Matrix.

The Front Panel contains different elements, such as pictures or boxes, that were added just as decorations for the background or in the scope of displaying essential information about the general working principle of the LabVIEW application. As previously mentioned, the Front Panel is covered by a Tab Control with five windows, and each of them includes one primary (big) 8x8 LED matrix and eight secondary (minor) 8x8 LED matrices. Also, the other common graphical elements are a switch button (vertical rocker) for turning on and turning off the automatic running of the animation, a combo box to choose the desired animation from the drop-down list, 9 x 2D arrays of Boolean controls for illustrating the primary and secondary LED matrices and additionally, 8 x 1D arrays of Boolean controls located in the fifth Tab, for implementing the conversion between the binary values (led = on or led = off) and the hexadecimal values.

This LabVIEW application provides the simultaneous simulation of the user-customized graphical effects both on the virtual and physical LEDs matrix connected to Arduino Uno. Therefore, an additional LabVIEW toolkit – LabVIEW Interface for Arduino – enabled the communication with Arduino and offered access to the SPI-related virtual instruments necessary to turn on and off each individual LED from the 8x8 matrix controlled by the MAX7219 driver. The graphical functions sequence of LabVIEW & Android is composed of: Init – Arduino Connection, SPI Init, SPI Set Bit Order, SPI Send Receive, SPI Close, and Close – Arduino Connection. It is essential to prepare the data in a suitable format to be connected to the SPI Send/Receive Data Bytes on the SPI bus of the Arduino board. The structure of the sent/received data is 1D numerical array, and it is based firstly on the virtual main Boolean 8x8 LEDs Matrix used to simulate the graphical effect in LabVIEW and secondly, on a 1D array composed of 8 elements of unsigned byte type (8-bit integer: 0 – 255) for defining the binary codes. The implementation of the Arduino SPI communication in LabVIEW constitutes a customized version of the code sequence presented to the Internet source [18].

The implementation of the Block Diagram underlying the third presented LabVIEW application can be entirely checked to the video clip uploaded to the YouTube link [22]. Also, in the initial stage of implementing the LabVIEW application for simulating the graphical effects, the programming approach focused on turning on and off each individual LED directly in the Block Diagram, resulting in various animated patterns - YouTube link [23]. Nevertheless, according to the obtained Block Diagram, the initial LabVIEW programming approach involved too much effort and time.

3.4. Controlling the LEDs based Virtual Display Systems by Creating a Graphical Animation using a Brain-Computer Interface based on the detection of voluntary eye-blinks

As a scientific significance of the proposed LabVIEW-based Virtual Display Systems, this section presents the integration between the brain-computer interface (BCI) technology and creating the graphical animations by turning on and off the virtual LEDs (Figure 4). Therefore, calling the necessary functions included by the ThinkGear driver achieved the Bluetooth communication between the portable headset NeuroSky Mindwave Mobile and the LabVIEW application running on the Windows-based computer. The NeuroSky headset is used to acquire the electroencephalographic (EEG) signals from the prefrontal lobe (FP1 location according to the 10-20 International System) located on the forehead. The subject should execute voluntary eye-blinks to turn on and off the virtual LEDs to generate a particular pattern composed of multiple red-colored or grey colored LEDs. The ThinkGear driver offers a specific function for measuring eye-blink strength. If the user performs intense eye blinks (characterized by an amplitude higher than the initially established threshold), the LED is turned on, meaning it gets red-colored. If the user performs mild eye blinks (characterized by an amplitude lower than the initially established threshold), the LED is turned off, meaning it gets grey-colored. There resulted in a series of numerical arrays composed of 8 elements given by ones and zeroes converted into Boolean arrays consisting of 8 elements provided by the values true and false. The binary values 1 and 0 show if the condition given by the statement – is the measured eye-blink strength higher than the established threshold – was fulfilled or not by the user. The value = 1 (one) is inserted in the array when the user executes a strong eye-blink. When the user achieves a mild eye blink, the value = 0 (zero) is added to the array. Similarly, a true value is used to turn on an LED when the user performs a strong eye blink, and a false value is necessary to turn off an LED when the subject acts a mild eye blink.

Both the Front Panel (the graphical user interface in the running mode) and the Block Diagram (the source code implemented according to the above-explained algorithm) can be checked in a video demonstration uploaded to YouTube [24].

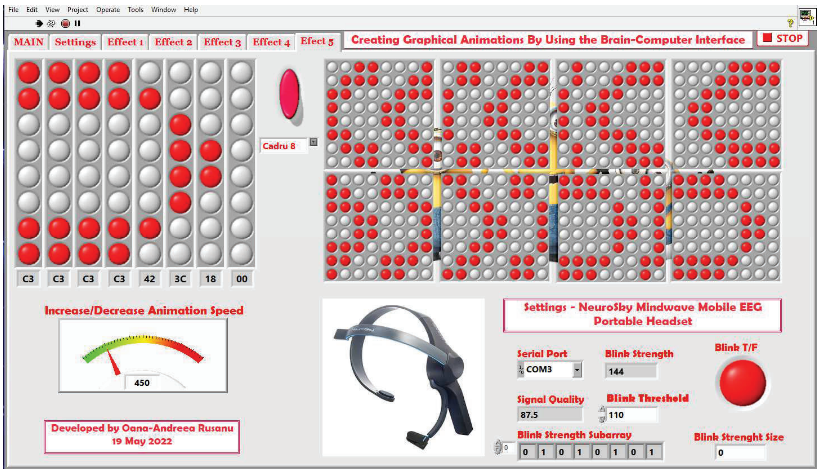

Figure 4. The Front Panel of the LabVIEW Application aimed to control the LEDs based Virtual Display Systems by using a Brain-Computer Interface.

3.5. Augmentative and Alternative Communication Device or Interactive Display System of Messages to a 2x16 LCD TEXT

The paper presents the fourth customized LabVIEW application (Figure 5) to show and run different text messages to the virtual liquid crystal display with two lines of 16 characters each (2x16 LCD TEXT) and the physical, electronic display (the same model) connected to the Arduino Uno board. Therefore, some versatile applications of this LabVIEW virtual instrument could enable the augmentative and alternative communication or an interactive display system of character strings transmitting information necessary for different purposes and locations (station, waiting room from medical centers, advertising messages for pharmacy). Regarding the design of the display, the inspiration was brought by the Logitech brand of 2x16 LCD TEXT with two rows of 16 characters, each meaning 7x5 LEDs matrices. The virtual 2x16 LCD TEXT accomplishes four main features. The first one is inserting and displaying text messages on the first and second lines. The second one is the running or movement of the displayed text messages on the two lines. The third one is changing the displayed text message's movement direction (to the left or the right). The fourth one is adjusting the running speed during the left or the right movement direction of the displayed text message.

Thus, the LabVIEW application based on the LCD TEXT 2x16 provides several further described features. The user can type into the first or second line a string with the maximum size of 70 characters that can be entirely shown on display by running the text in the left direction. The user can type into the first and second line a string with the maximum size of 16 characters that can be circularly shown on display (entering to the left side and leaving the screen to the right) by running the text to the right. The user can write any text by using 26 different letters of the alphabet, ten digits (from 0 to 9), and many punctuation marks: ! # , $ % & ' ( ) * + - _ . / : ; < > ? [ ] { } ^ = --> <--. The user can insert and display any text using uppercase and lowercase. The user can use the two lines to display a text with a maximum size of 16 characters.

The user benefits from additional functionalities: turning on and off the mobile displaying of the introduced text; switching the movement direction (to the left or the right) of the displayed text message; increasing or decreasing the running speed of the inserted text; parallel running of both lines of text by setting either different movement directions or the same movement direction; special buttons – switches and meter – to activate or deactivate a specific feature and reduced memory size and smooth execution facilitated by the efficient programming framework.

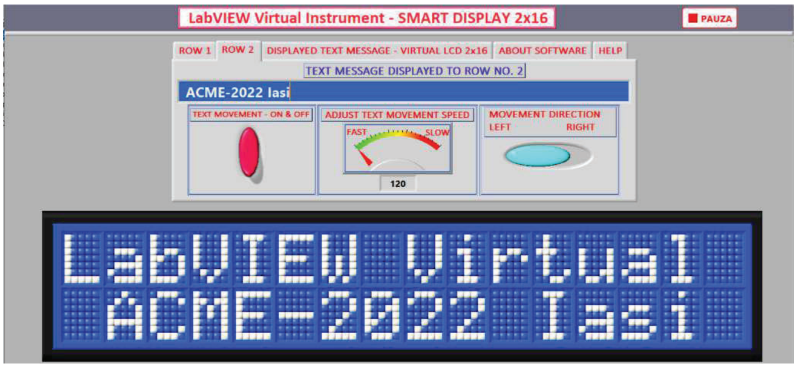

Figure 5. The Front Panel (The Graphical User Interface) of the fourth LabVIEW Application that enabled the Interactive Running of Text Messages to the Virtual 2x16 LCD TEXT.

The Front Panel of the currently described LabVIEW application comprises several graphical user elements that are further described. A panel constitutes the virtual display or the 2x16 LCD TEXT – built from 2x16 clusters, resulting in 32 groups with 7x5 LEDs each. The Tab Control with four windows comprises various components. The first window and second window have similar content. A string control is used for inserting the desired message on the first line (for the first window) and second line (for the second window) of the LCD TEXT 2x16. A switch button (vertical rocker) is used for turning on and off the movement of the displayed text message on the first/second line of the LCD TEXT 2x16. A meter is necessary for increasing and decreasing the movement speed of the displayed text message on the first/second line of the LCD TEXT. A switch button (horizontal slider) is necessary for changing the movement direction of the displayed text message on the first/second line of the LCD TEXT 2x16. Decorations and labels are added to improve the visual appearance and customize the background. The third window includes two rows of 16 combo boxes each for displaying a list including the 26 letters of the alphabet and letting the user select either lowercases or uppercases displayed on the LCD TEXT 2x16. The fourth window describes the main useful features provided by the LabVIEW-based LCD TEXT 2x16. The fifth window contains valuable information to help the user explain the necessary steps to get a better experience.

In addition, the currently presented LabVIEW application comprised the implementation of the chronometer functionality (Figure 6) displayed to the 2x16 LCD TEXT in the format: minutes – seconds – centiseconds (tens of seconds).

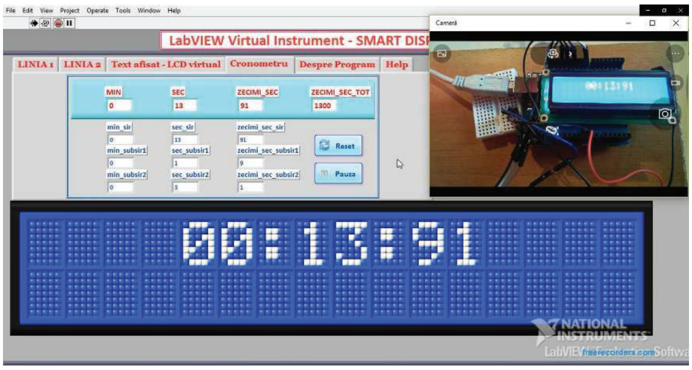

Figure 6. The Front Panel of the fourth LabVIEW Application that allowed the Simulation of the Chronometer Functionality to the Virtual and to the Arduino-based 2x16 LCD TEXT.

This LabVIEW application was interfaced with the Arduino Uno board by transferring the text message to the virtual and physical display – the 2x16 LCD TEXT. Therefore, an additional LabVIEW toolkit – LabVIEW Interface for Arduino – provided the functions necessary to communicate between the computer and the Arduino board. The following sequence of functions was introduced in the LabVIEW Block Diagram: Init – Arduino Connection, LCD Configure 4-bit, LCD Init, LCD Set Cursor Position, LCD Print (connected to the character string representing the displayed text message), LCD Set Cursor Position, LCD Scroll Display (connected to the left or right direction based on the user choice) and Close – Arduino Connection. General LabVIEW programming structures (While loop, Case Structures) and Wait functions are also used.

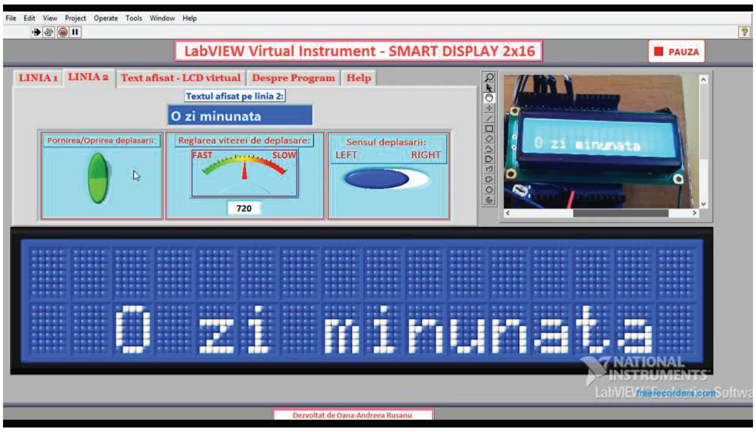

Figure 7. The Front Panel of the fourth LabVIEW Application that allowed the Simulation of the Chronometer Functionality to the Virtual and to the Arduino-based 2x16 LCD TEXT.

The content of the Block Diagram underlying the fourth presented LabVIEW application can be entirely checked to the video clip uploaded to the YouTube link [25-26].

3.6. Controlling the Augmentative and Alternative Communication System based on the Virtual 2x16 LCD System by Sending Text Messages using a Brain-Computer Interface based on the detection of voluntary eye-blinks

Considering the scientific significance of the proposed LabVIEW-based virtual 2x16 LCD system, this section presents the integration between the brain-computer interface (BCI) technology and sending text messages by selecting the corresponding buttons using the voluntary eye-blinks (Figure 8).

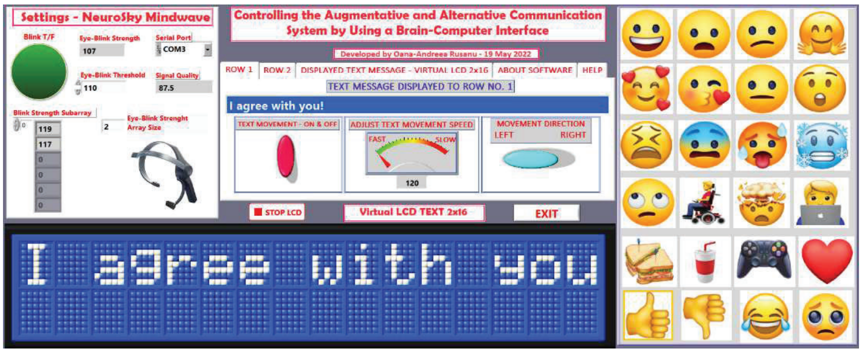

Figure 8. The Front Panel of the LabVIEW Application aimed to control the Augmentative and Alternative Communication System by Using a Brain-Computer Interface.

Regarding the communication between the portable EEG headset and the LabVIEW environment, it was used the same LabVIEW implementation, based on the ThinkGear driver of functions, that was previously described in section 3.4. Also, it was designed a similar state-machine paradigm to get the total number of voluntary eye blinks. As a difference, one voluntary eye-blink needs to be performed to switch across the options given by the various buttons corresponding to different text messages, and two voluntary eye-blinks should be executed to select the desired option and display the associated message to the virtual 2x16 LCD system. Moreover, it was also added an additional programming sequence to highlight the currently selected button by coloring it blue.

Both the Front Panel (the graphical user interface in the running mode) and the Block Diagram (the source code) of the proposed application can be checked in a video demonstration uploaded to YouTube [27].

3.7. *Implementation of the Chronometer Functionality to the 7-LEDs segments and 8-Digits Display*

This paper presents the fifth customized LabVIEW application (Figure 9) to implement the algorithm underlying a chronometer with the format minutes – seconds – centiseconds and simulated as a virtual display with eight digits and seven segments. The virtual Chronometer is featured with two functions: pause – for taking a break and freezing the current time interval and reset – for re-initializing the number of minutes, seconds, and centiseconds to the value equal to zero. As a user interface background, a picture showed the Serial 7-segments Display 8-Digits developed by Mikroelektronika.

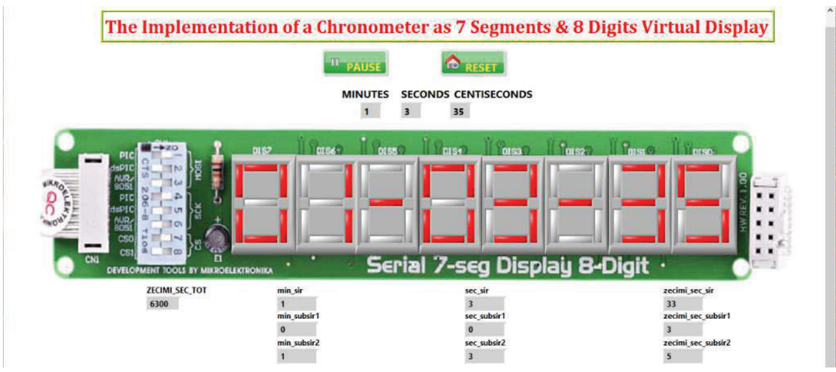

Figure 9. The Front Panel (The Graphical User Interface) of the fifth LabVIEW Application that enabled the Implementation of the Virtual Chronometer as 7 Segments & 8 Digits Display.

The Front Panel of the currently described LabVIEW application (the chronometer functionality achieved as a virtual display with 7-segments and 8-digits) comprises several further described elements. Three numeric indicators displayed the incremented values for minutes, seconds, and centiseconds. One indicator of numeric type was necessary for displaying the total number or the sum of centiseconds that were added/incremented since the Chronometer started. Two buttons or Boolean controls were used for switching between binary states: pause on – pause off and reset on – reset off. Nine string type indicators were introduced to display the current value, the number of units, and the number of tens corresponding to centiseconds, seconds, and minutes. Eight clusters represented groups of 7 square LEDs (Boolean indicators with two states: red-colored led = on and white-colored led = off) displayed as seven segments arranged in the shape of the digit 8 (eight), resulting in (by reading from right to left): 2 clusters for illustrating the current value of centiseconds; 1 cluster for lighting up the segment fulfilling the role of a delimitation line; 2 clusters for showing the current value of seconds; 1 cluster for lighting up the segment fulfilling the role of a delimitation line and 2 clusters for presenting the current value of minutes. There were also added different decorations, smooth vertical boxes, raised frames, and a picture for customizing the background, the title, and designing the appearance of each digit shaped like an eight, including the group of the seven segments.

The content of the Block Diagram underlying the fifth presented LabVIEW application can be entirely checked to the video clip uploaded to the YouTube link [28].

3.8. Involving the Chronometer Functionality based on the 7-LEDs and 8-Digits Display System in a Brain-Computer Interface Application based on Recording EEG Signals according to Setting Time Windows for Executing Cognitive Tasks

As the scientific purpose of the proposed LabVIEW based Chronometer displayed on the virtual system with 7-LEDs and 8-Digits, this section presents the integration between the brain-computer interface (BCI) technology and the elapsed time interval from the total duration set for the acquisition of the raw EEG signal detected by the embedded sensor of the NeuroSky portable headset (Figure 10). Therefore, the BCI LabVIEW based application benefits from a new graphical user interface used for the automatic mode of EEG data acquisition by setting the target duration (for example, 30 seconds) and the time interval (for example, 2 seconds) for getting several time windows (for instance: 15-time frames) composed of raw EEG data values (for example, 2 x 512 = 1024 raw EEG values) showing the EEG pattern associated with the cognitive task performed by the user (for example, a voluntary eye-blink). Then, taking into account the features provided by the brain-computer interface application, each recording of 1024 raw EEG values is graphical displayed on a chart and used in the further stages of signal processing, features extraction, and generation of EEG data training datasets and classification of Neural Networks based models.

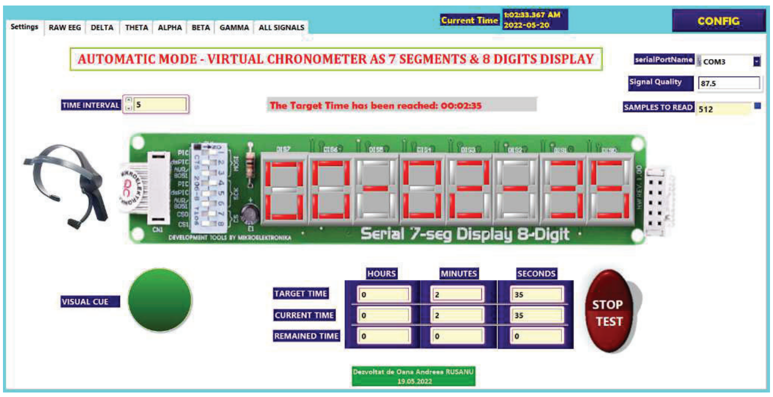

Figure 10. The Front Panel of the LabVIEW Application aimed for Automatic EEG Data Acquisition, according to set time windows, in a Brain-Computer Interface.

Both the Front Panel (the graphical user interface in the running mode) and the Block Diagram (source code of the above-described functionalities) of the previously presented LabVIEW application are shown in the video demonstration uploaded to YouTube [29].

4. Results and Discussions

Regarding the results of the presented LabVIEW applications, some live video demonstrations showing their features, functionalities, and working principle were uploaded to YouTube. The videos [19-20] show the Binary to Hexadecimal Conversion Algorithm Applied to an 8x8 LEDs Matrix. The video [21] presents the Hexadecimal to Binary Conversion for Running Graphical Effects to an 8x8 LEDs Matrix. The videos [22-23] and [30] contain the Simple Design and Automatic Running of Graphical Effects to a Virtual and a Real 8x8 LED Matrix Connected to Arduino Uno. The videos [25], [27], and [31-32] include the Augmentative and Alternative Communication Device or Interactive Display System of Messages to a 2x16 LCD TEXT. The videos [26] and [28] comprise the Implementation of the Chronometer Functionality both to the 2x16 LCD TEXT and Display System with the 8 digits and 7 LED segments. The video [29] presents the live demonstrations of the simple brain-computer interface applications for controlling the virtual display systems based on LEDs matrix and LCD text.

Indeed, the block diagram of the proposed LabVIEW applications may be improved by implementing more efficient programming paradigms and different functions and adding new versatile features. Currently, the presented LabVIEW-based algorithms address the novice and intermediate students who are willing to develop specific thinking patterns and better understand some basic concepts underlying the programming of microcontrollers by experimenting with versatile simulations of virtual and physical display systems. Moreover, beyond the educational purpose of the proposed LabVIEW applications, the virtual display systems can also be used in the medical assistance of people with disabilities. The 2x16 LCD TEXT can display text messages that indicate an augmentative and alternative communication system depending on the selected button. The 8x8 LEDs Matrix can be extended to a bigger size and configured to generate specific frequencies of turning on and off the LEDs or set to simulate graphical effects necessary to elicit common patterns known as P300 and SSVEP (Steady-State Visually Evoked Potentials) or SCP (Slow Cortical Potentials) across the electroencephalographic signal acquired, processed and classified into commands for a brain-computer interface system. Nevertheless, the current fundamental roles of the proposed LabVIEW applications consist in providing interactive, versatile, and rapid solutions for creating and simulating an animation or a graphical effect displayed to LED matrices for entertainment purposes; typing and running text messages displayed to LCD TEXT for simple transmitting a piece of essential information; implementing and executing the chronometer function displayed to the system with eight digits and seven segments for general use.

Regarding fulfilling the previously mentioned roles, neither the working principle nor the performance of the developed LabVIEW applications requires no improvements because the virtual display system runs smoothly and flexibly. There are no delays between the transition from the previous to the next frame during the running of graphical effects to the LED matrix or regarding the movement of the message displayed on the LCD TEXT in the left or the right direction. Among the limitations of the LED matrix to display the graphical animations, the maximum size set to 8 rows and 8 columns can be mentioned. Likewise, regarding the boundaries of the LCD TEXT aimed at displaying messages, the full size set to 70 characters during the transition to the left of the inserted string and 16 characters during the transition to the right of the introduced string can be noticed. A possible limitation of the implemented LabVIEW-based Chronometer is the maximum time interval of 60 minutes that can be set. The seconds and minutes are incremented with the same accuracy, as reported by the clock/time embedded by the operating system. Nevertheless, the Chronometer's precision is high because the iteration time interval is ten milliseconds.

5. Conclusions

This paper proposes various simple brain-computer interface (BCI) instruments based on controlling five customized and original LabVIEW applications aimed at designing interactive virtual displays achieving versatile functionalities. The BCI systems involved EEG signal acquisition from the embedded sensor of the NeuroSky portable headset. The control signal referred to the voluntary eye-blinks used as commands for turning on and off the LEDs to create different patterns of graphical animations and to display text messages. Also, the chronometer functionality provided by the virtual display system helps monitor the entire time duration for the EEG data acquisition and the generation of time frames when the user should perform a cognitive task. This way, the first and the second developed LabVIEW applications were based on creating an 8x8 LEDs matrix for implementing the algorithms underlying, firstly, the conversion between binary and hexadecimal numerical systems that can be further used in programs written in C programming language, and secondly, the conversion between hexadecimal to binary Boolean values to generate animated frames and trigger the automatic running of a graphical effect. Also, the third presented LabVIEW application allowed the user to manually turn on and off a series of LEDs and create a particular pattern resulting in an animated frame that can be included in the graphical effect.

Moreover, the fourth implemented LabVIEW application was composed of a virtual display – 2x16 LCD TEXT– to present and run different messages. Finally, the fifth proposed LabVIEW application included implementing and simulating the chronometer functionality displayed on the system with eight digits and seven segments. Although all these virtual instruments are based on general LabVIEW programming functions and structures, they resulted in an efficient, smooth, and attractive real-time execution.

Regarding the future research directions, the intention is to leverage the previously described LabVIEW instruments for implementing additional versatile applications of brain-computer interfaces (BCI) or augmentative and alternative communication (AAC) systems that are frequently used to assist people with disabilities.

6. References

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