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Facial expressions as an artifact in EEG signal used in the process of controlling a mobile robot with LabVIEW

Abstract. This paper describes the control of a mobile vehicle by means of LabVIEW environment and artifacts in the EEG signal. The solutions by Emotiv and the LabVIEW environment were combined in order to conduct an electrophysiological data analysis as a function of time correlated with a specific potential. Artifacts occurrence in a given area was analysed by means of the EEG signal, which was measured with electrodes. The input signals processed were used in order to control a real object in the form of a mobile vehicle.

Streszczenie. W artykule opisano kwestię sterowania pojazdem mobilnym przy wykorzystaniu środowiska LabVIEW oraz artefaktów pojawiających się w sygnale EEG. W pracy dokonano połączenia rozwiązań udostępnianych przez firmę Emotiv ze środowiskiem LabVIEW w celu przeprowadzenia analizy danych elektrofizjologicznych w funkcji czasu, skorelowanych z konkretnym potencjałem. Występowanie artefaktów w danym obszarze analizowane było w oparciu o sygnał EEG, który mierzony był za pomocą elektrod. Przetworzone sygnały wejściowe użyte zostały na potrzeby sterowania obiektem rzeczywistym w postaci robota mobilnego. Sterowanie pojazdem mobilnym przy wykorzystaniu środowiska LabVIEW oraz artefaktów pojawiających się w sygnale EEG

Keywords: artifacts analysis in EEG signal, LabVIEW environment, control, mobile robot
Słowa kluczowe: analiza artefaktów w sygnale EEG, środowisko LabVIEW, sterowanie, robot mobilny

Introduction

Nowadays, many research units in the world conduct research on the development of new control methods, including technologies based on electrophysiological signals [1]. Electrophysiological signals, such as EMG or EOG, introduce interference to EEG signals. Such interference is called artifacts. A brain-computer technology is currently developed mainly due to the EEG signal analysis, which is implemented in intrusive and non-intrusive methods in practice [2]. Experimental research works conducted at the Laboratory of Neuroinformatics and Decision-Making Systems of Opole University of Technology are based on the non-intrusive method [2]. In this case the EEG signal, including EEG artifacts, is taken by means of the electrodes placed on the surface of the head [3]. However, it is not the only method of creating brain-computer interfaces, but it is easier to implement as opposed to, for example, magnetic resonance imaging.

It is noteworthy that the LabVIEW environment that has been chosen for this research and experimental work, has already been used in Poland for neuro-feedback, that is for a self-training of our brain with the use of the BCI2000 platform [4].

Emotiv EPOC+ NeuroHeadset

Emotiv EPOC+ NeuroHeadset was used for the purpose of the research experiment. Its advantages are a high resolution of data obtained in a short time, relatively quick calibration and a very good value for money, whereas its disadvantages are noticeable time delays in signal transmission to the workstation. EPOC Control Panel is the first program that is run after the Emotiv EPOC+ NeuroHeadset is set up. After the appliance is placed on the head, it must be checked whether all electrodes touch the skin properly.

Mobile vehicle

A prototype robot model was made in order to physically execute the control process. It is shown in Figure 1. Microcontroler Texas Instruments C2000™ Piccolo LaunchPad was used in this project. It controls the H bridge and shows/emits information for the operator by means of 2 LEDs and a sound-emitting system (buzzer). The requirements of the drive system are as follows: the execution of robot movement in assumed environment conditions; execution of generating and using appropriate power; ensuring as low mass per unit power as possible; easy control of the drive system, which includes smooth change of the position, speed control – both of the absolute value and acceleration and speed signs, and sometimes power control; ability to manually move the robot without the risk of destroying its wheels and steering system.
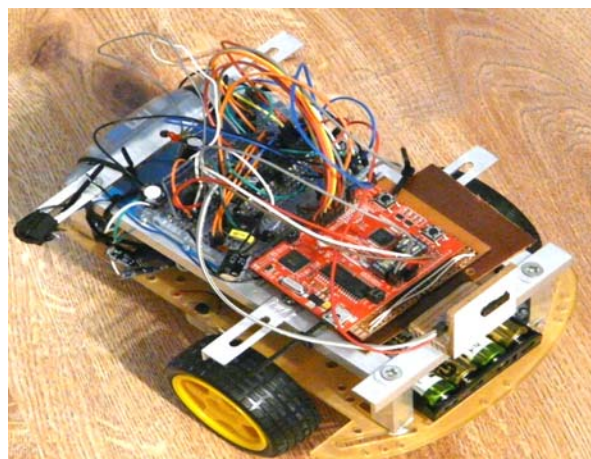

Fig. 1. Mobile vehicle prototype

A simple and cheap 130-size brushed 6V DC motor with gear ratio 1:48 was used in this project.

The next element designed for the purpose of the experiment was the robot body. Its task is to ensure all elements, such as sensors, drive systems and actuators, are firmly secured and to protect robot parts from damaging due to external factors or colliding with obstacles. The chassis of the robot was made of 22x12 cm acrylic glass on which all other robot parts were placed. Three flat bars were also used and they serve as bumpers.

For the purpose of the research experiment, the robot was equipped with IR sensors which stop the robot in order to avoid collision with obstacles, e.g. during the communication system failure, false control signals readings etc.

It is worth noting that almost all mobile robot designs are powered by different types of batteries. In larger designs lead-acid batteries are used, whereas smaller designs use

NiCd, NiHN, Li-ion, and LiPo batteries. This robot vehicle is powered by: 10 1.2V batteries; 4 AAA Eneloop batteries powering sensors; the H bridge and microcontroller; 6 AA Eneloop batteries powering the motors. The motors were controlled by the microcontroller using the H bridge. To that end, integrated circuit L293d was used. It is a dual motor driver that works at a voltage up to 36V and supports an average current of 600 mA per channel. The package was DIP 16 (through-hole mounted).

LabVIEW environment

Due to a very small number of available solutions and its correlation with BCI technology, LabVIEW was chosen as a development environment. Moreover, the LabVIEW environment has many built-in features used to communicate with multiple devices. Another advantage of LabVIEW is a wide range of functions to visualise data [5]. In order to build the program, a mechanism for joining icons that is available in the environment was used. A sample EEG signal reading from 14 electrodes in the LabVIEW program is shown in Figure 2.
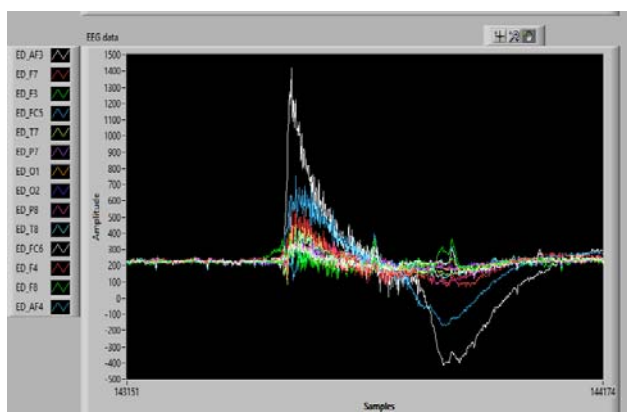
Fig. 2. Sample EEG signal reading from 14 electrodes in the LabVIEW program

In order to connect Emotiv EPOC+ Neuroheadset with the computer, the LabVIEW Emotiv Toolkit V2 package was implemented. The package only works with a 32-bit version of LabVIEW and requires the user to show the exact location of the original edk.dll file. The package allowed for the use of all signals implemented by Emotiv. In this way it is possible to verify whether facial expression readings are correct or not by simultaneously looking at them in the EPOC Control Panel program. A virtual graphical user interface – GUI panel where LEDs were placed (Fig. 3) was created in order to ensure the LabVIEW program reads signals correctly. A smile or other previously identified facial expression generated a light pulse in a corresponding LED. The available package returns True or False values by default (Fig. 4). However, in case of clenching your teeth the package returns a figure, therefore for clenching the value above zero was replaced with True.

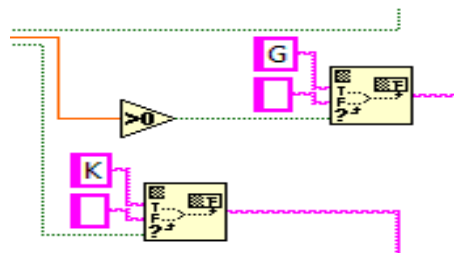Fig. 3. LED controls used to detect a given signal model

Fig. 4. Changing True signal to a given robot action sign according to Table 1

Mobile robot control

The research experiment was conducted on the basis of Emotiv EPOC+ NeuroHeadset. The difference between EPOC+ and EPOC is a higher sampling rate of the signal measured of the former. For the purpose of the task, LabVIEW was chosen, which is based on G programming language and one of the niche development environments for such purposes so far [6]. The electroencephalographic signal was obtained due to the research licence of the Laboratory of Neuroinformatics and Decision-Making Systems of Opole University of Technology for Emotiv hardware and software containing Emotiv SDK with access to data in a *.raw format. Software Development Kit is a set of developer tools vital for writing applications that use a given Emotiv library.

For the purpose of the control process execution, signs were defined corresponding to specific actions - movement directions of the robot - which is shown in Table 1.

Table 1. Signs corresponding to actions/movement directions of the robot

Action/movement direction	Sign
Forward	G
Back	T
Stop	S
Horn	K
Right	P
Left	L
Reset	R

In the first testing phase, the connection with the mobile robot was established via Bluetooth pairing with the computer on MS Windows 7. Then the port was chosen in the LabVIEW environment, e.g. COM7. The disadvantage of such a solution was the necessity of pairing the robot with MS Windows 7 every time in order to establish the connection. After the port is chosen, any sign can be sent in the panel in order to check whether the connection is properly established.
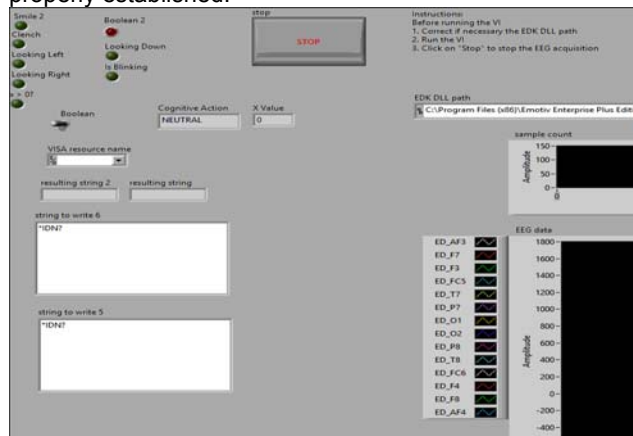
Fig. 5. Graphical User Interface panel

The GUI panel shown in Fig. 5 is composed of the following elements: String to write – test signs sent to the mobile robot; Resulting string – signs received or testing whether signs are sent; X Value – current gyroscope data on X axis (horizontal); STOP – program execution; Boolean – emergency switch, it resets the signs received in the mobile robot; Cognitive Action – current learned signal, the same as the signal while controlling a cube in EPOC Control Panel; Sample Count – graph showing the proper receiving of samples from the electroencephalograph; EEG Data – graph showing EEG signal readings from 14 electrodes; VISA resource name – COM port of the synchronized robot.
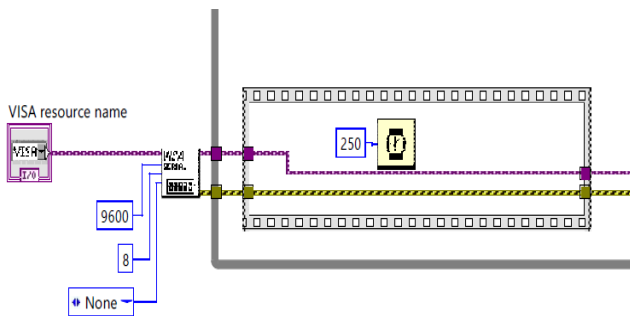

Fig. 6. Part of the program in LabVIEW responsible for communication

In Fig. 6 the following work parametres of the program were defined: baud rate 9600, 8 bits of data, and 250ms delay - ¼ of a second, so sending was at a frequency of 1 Hz for the C2000 microprocessor.

In order to control the mobile robot on the basis of potentials evoked in Table 2, facial expressions were assigned to the actions/movements directions described above. This table correlates with Table 1 as far as the first column is concerned.

Tab. 2. Facial expressions corresponding to the actions/movement directions of the robot

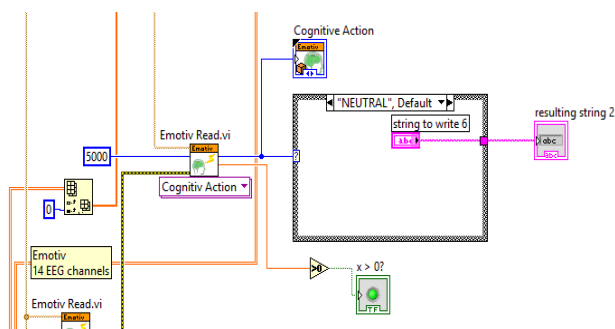| Action/Movement direction	Facial expression
Forward	Clench
Back	Looking down
Stop	Smile
Horn	Blinking
Right	Looking right
Left	Looking left
Reset	Emergency switch on the console

Fig. 7. Attempt to use learned signal in the LabVIEW environment

Evoked potentials tests were the basis for creating the control system (Fig. 7). The experiment was based on finding signals that the robot operator identifies at an

efficiency of 100%. To that end, EPOC Control Panel was used. As shown in the experiment conducted, expressions such as smile, clench, blinking were executed at a high efficiency and high interference rejection. Tests that involved rotating a solid – the cube – were much more difficult to execute because its signals identification and classification require maximum focus. A sample change of the EEG signal amplitude versus time for blinking fivefold is also shown in the LabVIEW graph (Fig. 8).
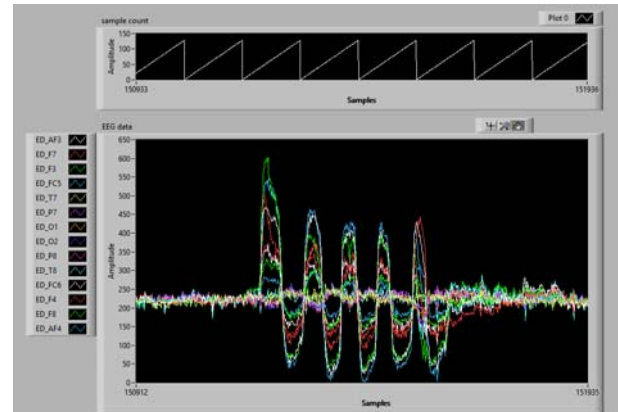

Fig. 8. EEG signal visualisation while blinking fivefold in LabVIEW

The change characteristics of the EEG signal amplitude on particular transmission channels are shown in Fig. 9, whereas Figures 10 and 11 show the EEG signal amplitudes versus time for the robot operator looking left (Fig. 10) and right (Fig. 11).
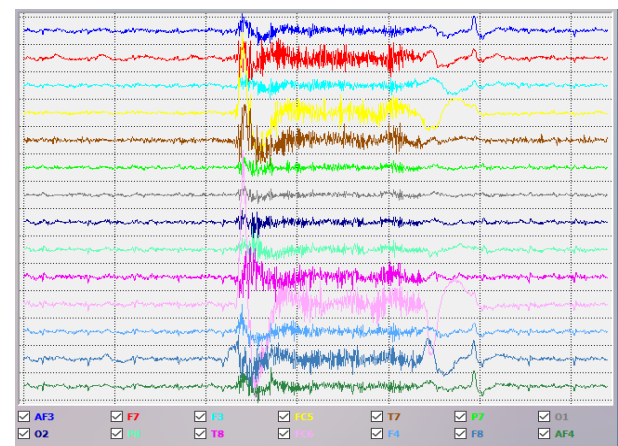

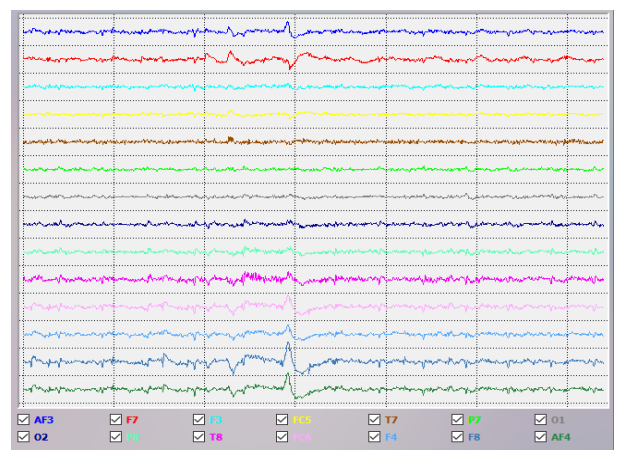Fig. 9. EEG signal amplitude change while clenching

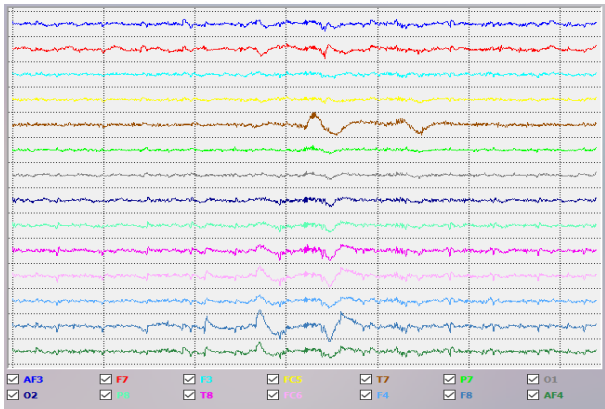Fig. 10. EEG signal amplitude change while looking left

Fig. 11. EEG signal amplitude change while looking right

Figure 12 shows the EEG signal amplitude change in the LabVIEW environment while smiling.
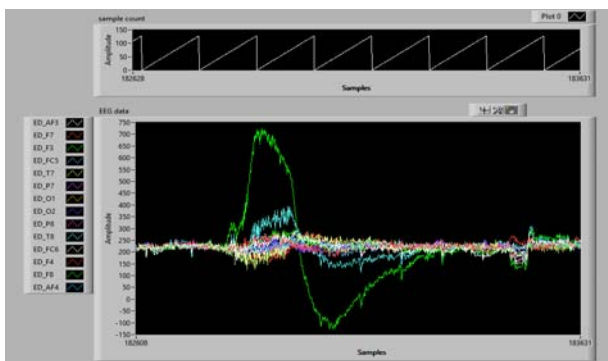

Fig. 12. EEG signal amplitude change while smiling in LabVIEW.

EEG signals amplitudes presented in this paper show differences in detecting particular signals, for example the electroencephalogram of looking right (Fig. 11) differs considerably from the electroencephalogram of looking left (Fig. 10), in which case two additional electrodes receive the electric pulse present while looking right. The LabVIEW environment shows EEG reading on a different scale; therefore, the signal corresponding to smiling is noticeable more clearly (Fig. 12). Clenching generates a strong signal on all channels (Fig. 9). Blinking either a left or right eye is recognisable as in the case of looking. The EEG blinking signal is reflected best because on its basis it can be easily identified how many times the robot operator has blinked (Fig. 8).

In conclusion, as shown in the tests conducted, the real-time control of the robot is only possible while being entirely focused and yet some interfering artifacts may still occur. Therefore, it is important to filter the signal using, for example, FFT. Constant development and creation of new algorithms used to identify and filter interference will certainly allow for the use of the electroencephalograph in automatic control engineering and robotics on an even bigger scale.

Research and experimental work
Many control sessions were run to verify the process of controlling a robot conducted in the LabVIEW environment. The person who controlled the robot was siting. The process of electroencephalography signals registered at a given time was visualized at a workstation.

The efficiency of the process was very high when the person controlling a robot was alone in the room and kept the highest concentration level on his activity. The plug was downloaded from the official LabVIEW website in order to correlate the device Emotiv EPOC+ NeuroHeadset with LabVIEW. On the basis of the work performed, LabVIEW uses *.dll files from Emotiv Control Panel with its previous facial expressions detection in the mentioned application which has a significant influence on the process of controlling in LabVIEW. Thereby, it is worth noting that the plug used for the experiment works only with the x86 version of 32 bit LabVIEW environment. At each measurement session in LabVIEW, the facial expressions were converted into signs, numbers which were sent in series via Bluetooth to the workstation and then from the Bluetooth module to the robot. The robot decoded the signs for the control purpose.

It is noteworthy that while executing this control process in the case of gestures, there was a slight latency observed. The best control results have been received with for the following Facial expressions: Clench, Looking down, Smile, Blinking.

Conslusions
This paper describes the practical control process of the robot vehicle on the basis of the LabVIEW development environment. Based on the literature research conducted, it can be concluded that the number of similar executions of the use of the Emotive hardware potential in correlation with LabVIEW is very small. What is more, as far as the analysis and classification of EEG artifacts executed for the purpose of the robot control using Emotiv EPOC+ Neuroheadset with LabVIEW are concerned, such implementation attempts are one of the first of this type in Poland. The control of mobile vehicles using older Emotiv hardware and software (e.g. Emotiv EPOC NeuroHeadset) has already been researched both in Poland and in the world, but instead independent applications written in JAVA, C# programming languages were used in most cases. There are also other solutions becoming popular worldwide for mobile robot control based on the brain-computer technology like the devices of NeuroSky company [7]. However, NeuroSky MindWave Mobile devices have worse parameters, giving an advantage to the devices of Emotiv company. The LabVIEW environment, for instance, has been used so far in practice in the University in Taiwan to construct the intelligent system based on the BCI technology in correlation with potentials evoked [8].

As far as the executed experiments are concerned, it is worth considering the use of the radio frequency module RF or wireless LAN in the future to increase the range of a robot and to reduce the transmission errors. The research on creating its own driver to the device of Emotiv company is also planned, which would simplify considerably the work. In the future, it is also planned to carry out works on the assembly of the Rapberry PI or Intel Galileo module with the Emotiv software company in order to connect the Bluetooth module with the EPOC+ NeuroHeadset device.

In the future, mobile robots controlled using BCI interfaces may be implemented in many industries. Nowadays, however, they are used more often in entertainment sector. There is no doubt that BCI technology is becoming more and more popular due to the fact that an increasing number of companies and institutions develop it. Therefore, a huge progress in this field can be observed, as well as a decline in the price of equipment based on this technology. Due to the development of BCI technology and robotics, the equipment developed thanks to the technologies mentioned above is used to control wheelchairs by paralysed, physically disabled, elderly people, the number of which is increasing in modern Europe.

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