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STUDY OF THE POSSIBILITY OF USE OF BIOELECTRIC SIGNALS TO WIRELESS REMOTE CONTROL OF THE ELECTRO-PNEUMATIC POSITIONING SYSTEMS

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Abstract: *The aim of the study was to perform bioelectric signal analysis focusing on its applicability to wireless remote control of the electro-pneumatic servo-systems. The test-stand was constructed to wireless remote control of the electro-pneumatic servo-drive by means of bioelectric signals generated by the operator. The natural bioelectric signals generated by brain, facial muscles and eye muscles read by the NIA (Neural Impulse Actuator) are translated into control commands in the controller of electro-pneumatic servo-drive. Bioelectric signals (EEG, EMG and EOG) detected by means of special forehead band with three sensors are sent to the actuator box, where they are interpreted as control signals. The control signals from the actuator box are transmitted via a wireless WiFi network to the controller of pneumatic system. This paper proposes a novel Wireless Network Interface Controller (WNIC) for the control of pneumatic position system using bioelectric signals.*

Keywords: Bioelectrical signals, Wireless remote control, Electro-pneumatic positioning system.

1. Introduction

The brain and body provide a wealth of information about a person's physiological, cognitive and emotional states. There is an increasing trend to use physiological signals in computerised systems as an input control, and since entry level physiological sensors have become more widespread, physiological interfaces are liable to become pervasive in our society (e.g., through mobile phones). The three main components of the brain are cerebellum, cerebrum and brain stem (pons and medulla oblongata). Cerebellum is located between brain stem and cerebrum. Cerebellum controls facial muscle coordination, thus affecting signals (eye movements and muscle movements) by Brain-Body Interface (BBI) (Fairclough et al., 2011). Various devices read bioelectrical signals (e.g. electrocorticographic signals, skin biopotential or facial muscle tension) and translate them into computer understandable input. The concept of Brain-Computer Interaction (BCI) involves communication between a human brain, and an external computer device. Stimulating muscles, eyeball movement or a bioelectrical change in the brain's activity causes a change in people biopotentials, which may be measured and used as a control signal. Human-Computer Interface (HCI) enables people to control computer applications using bio-electric signals recorded from the body. Bioelectrical potentials (bio-potentials) are made up of four different signals (Gnanayutham et al., 2007): Galvanic Skin Response (GSR), Electrooculography (EOG), Electromyography (EMG), Electroencephalography (EEG). Bioelectrical signals may be also used for operating pneumatic servo system. The machine operator's reaction time may be significantly reduced if become equipped with an appropriate interface which measures and analyses bioelectric signals. Then sends appropriate control signals to the operated pneumatic servo system. A good example is an emergency stop of a device activated by pressing the emergency stop button using "thoughts", which would contribute to the safety of the pneumatic control systems. The use of wireless communication will also contribute to improvements in safety, particularly if the operator is right next to the operated

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machine. In order to test the use of bioelectric signals and wireless communication in the control of pneumatic position system a novel Wireless Network Interface Controller (WNIC) was built.

2. Test stand

The test-stand using bioelectric signals operator-generated signals for a wireless remote control of pneumatic positioning system was constructed. The natural bioelectric signals generated by brain, facial muscles and eye muscles read by the NIA (Neural Impulse Actuator) are translated into control commands in the controller of pneumatic servo system (Dindorf et al., 2015). Bioelectric signals (EEG, EMG and EOG) detected by means of special forehead band with three sensors are sent to the actuator box, where they are interpreted as control signals. The control signals from the actuator box are transmitted via a wireless WiFi network to the controller of servo-drive. The idea of wireless remote control of a servo-pneumatic positioning control system using bioelectric signals is shown in Fig. 1.

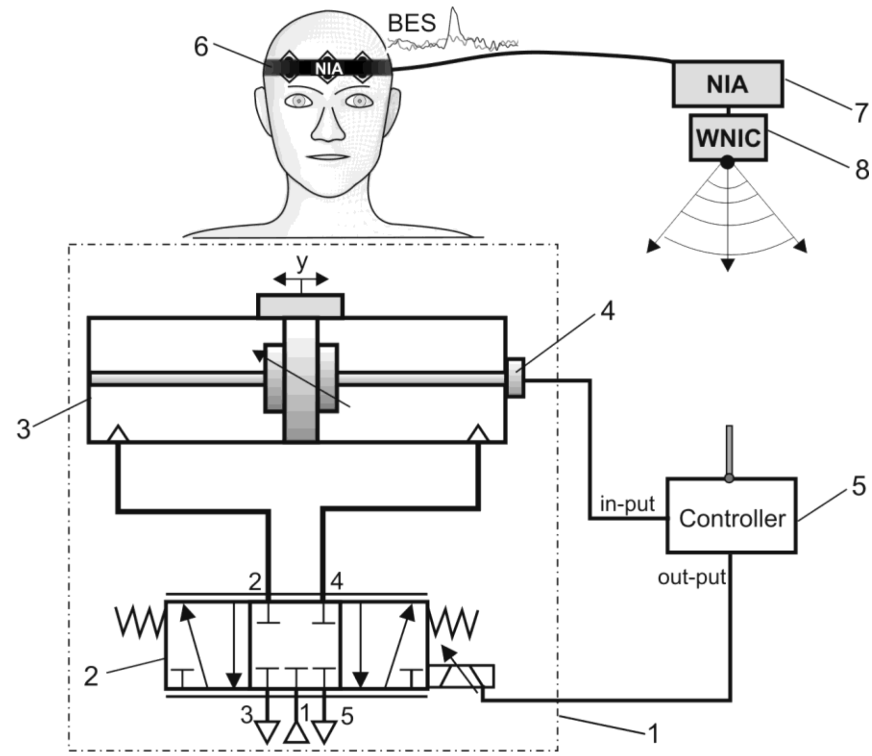

Fig. 1: The servo-pneumatic positioning system using the bioelectrical signals (BES) and a wireless network interface controller (WNIC): 1 – servo-pneumatic positioning system, 2 – proportional directional control valve, 3 – pneumatic rodless cylinder, 4 –displacement transducer, 6 – headband, 7 – Neural Impulse Actuator (NIA), 8 – Wireless Network Interface Controller (WNIC).

The pneumatic positioning system consists of the following elements:

- pneumatic rodless cylinder DGPL-25-224 (Festo) with piston diameter of 25 mm and stroke length of 224 mm,
- proportional 5/3 directional control valve MPYE-5-1/8-HF-010-B (Festo) controlled by 0-10 V voltage of nominal flow rate 700 l/min and switching frequency 75 Hz,
- non-contact micropulse displacement transducer BTL5-A11-M0600-P-S32 (Balluff), analog output signal – voltage 0-10 V.

The control operator has a band on their head with three electrodes, which record bioelectrical signals generated by the brain, face and eye muscles. The signals are then enhanced by the Neural Impulse Actuator (NIA), fed into a Wireless Network Interface Controller (WNIC) and analysed by appropriate software which is included with the device. The software generates control signals which are passed onto the application responsible for the controller - computer communication. Data between the computer and the controller are sent via a wireless IT network. On the basis of the value of the intended actuator position received from the operator and the current position the controller generates appropriate control signals. For adjusting the actuator position a PID controller was used, with the tuning done by the

Ziegler-Nichols method. The current actuator position is sent to the operator in order to verify the intended position. The wireless remote controller builds on a biosignal reader - Neural Impulse Actuator (NIA), microcomputer board ALIX.1D PC, data acquisition device MicroDAQ USB-1208FS, wireless card Ubiquiti XR2 and wireless network interface controller (WNIC) (Fig. 2). The ALIX.1D system board is equipped with an AMD Geode 500 MHz processors and 256 MB of RAM. It is powered by a 12V supply and has low power consumption, in the range of 0.4 to 0.5 A. The software for the servo drive and controller was written using the LabVIEW environment (Mazur et al., 2013).

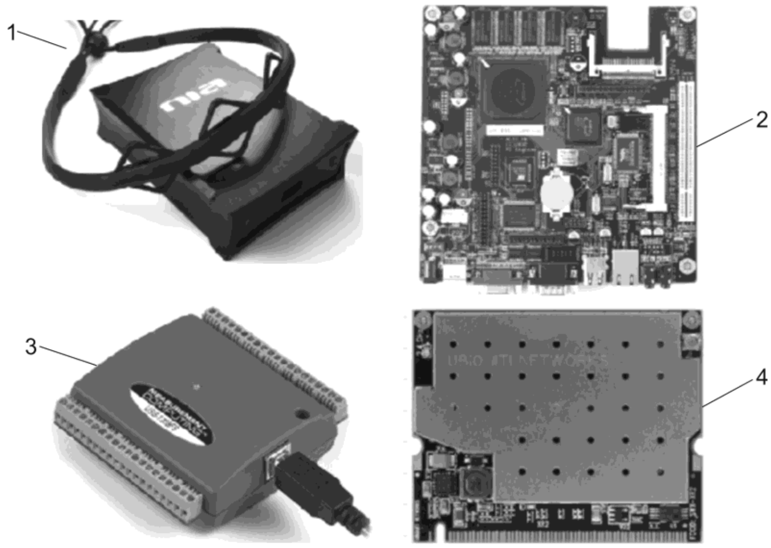

Fig. 2: Elements used for the controller construction: 1 – Neural Impulse Actuator (NIA), 2 – microcomputer board, 3 – module of the acquisition data, 4 - wireless network interface controller (WNIC).

The NIA device by OCZ is a BCI (Brain-Computer Interface) type interface equipped with a neurosignal reader (Hagedoorn et al., 2016), (Reynolds et al., 2009). The signals originating from the neural activity of the brain are captured by NIA in the form of electrical biopotentials which occurred as a result of Alpha and Beta brain waves, movement of the facial muscles and eye lids. Effective control of technical devices with the use of NIA requires a snug fit of the brain wave reader sensors to the forehead, calibration of the device and training. A dedicated application analysis of EEG, EMG and EOG biosignals together with one basing on appropriate bioelectric signal values as defined by the user, generate signals for pressing keys in the keyboard. The key to be pressed at a given bioelectric signal level is defined by the user in the application settings.

3. Control result

All available application level bio-electrical signals: muscle tension measurement, eyeball movement as well as Alfa and Beta waves were used in the experiment. Events simulating pressing appropriate keys on a keyboard were assigned to defined signal levels. Page Up - increase the actuator position value, Page Down - decrease the actuator position value, End - pressing of the emergency stop button. As a result of the conducted experiment, it was confirmed that the use of electromyography signals (EMG), for example by regulating the pressure of the tongue on the upper palate or clenching teeth with a larger or smaller force provides the best control signal generating effects. During the tests it was very difficult to precisely define the requested position of the actuator. Other bioelectrical signals did not facilitate determination of the pneumatic actuator (rodless cylinder) position, as it was difficult to obtain their appropriate level. The precision of position control of the electro-pneumatic servo drive may be increased by the operator undergoing appropriate training. As a result of the experiment the positional control characteristics of electro-pneumatic servo mechanism for different input signals were obtained (Dindorf et al., 2017). In Figs. 3 position control results of electro-pneumatic systems for ramp signal and follow-up signal are depicted. From analysis of above graphs it results that there is a delay between the value of set signal and actuator position. This delay is implemented by acquisition data module, since it results from the analysis program action that the most time take to generate voltage by the system. The second reason of acquisition data module delays is that communication with module takes place via USB interface, which isn't a real time interface.

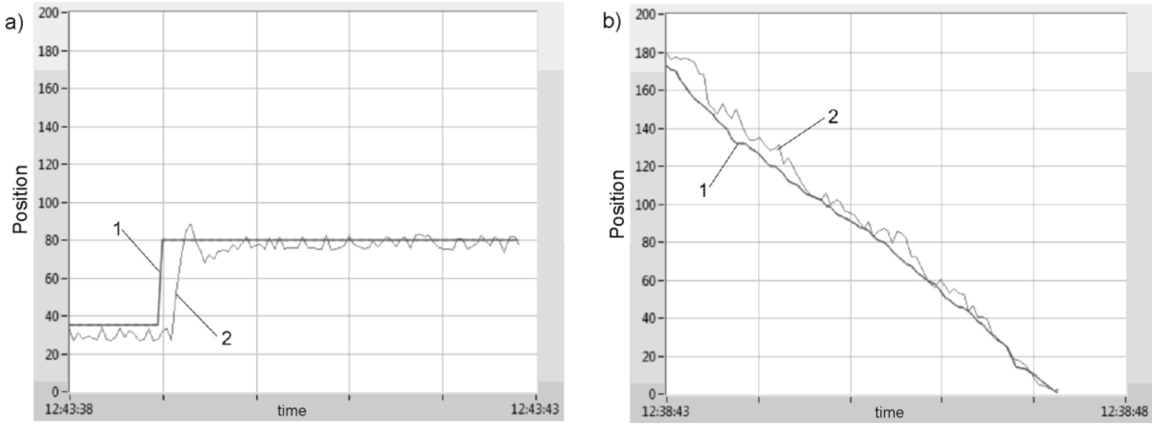

Fig. 3: Experimental position control results of electro-pneumatic system for: a) ramp signal; b) follow-up signal: 1 – setpoint position, 2 – current position.

Acknowledgement

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4. Conclusions

The conducted laboratory tests confirm that various bio-electrical signals may be used in the control process. It is easiest to use electrical activity signals generated by muscle movements (eyeball movement, clenching of teeth). This paper proposes a novel Wireless Network Interface Controller (WNIC) for the control of pneumatic position system using bioelectric signals.The bioelectrical signals subjected to appropriate training control may be used in systems not requiring significant position precision of pneumatic positioning system. They can also improve safety of a device by reducing operator's reaction time to sudden events, e.g.: emergency stop or faster operation of a break. In the NIA actuator the actual reaction times are about 30 % to 60 % shorter than what one can realistically achieve with emergency stop. The use of wireless communication increases operator's safety during device operation, as he does not have to be in the direct vicinity of the device. It also improves the mobility and reduces the cost of network infrastructure development and expansion. The control system using bioelectrical signal and remote wireless communication network was constructed and practically applied in pneumatic positioning systems.

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