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REMOTE CONTROL OF THE ELECTRO-PNEUMATIC SERVO DRIVE USING BIOSIGNALS

ZDALNE STEROWANIE SERWONAPĘDU ELEKTROPNEUMATYCZNEGO ZA POMOCĄ BIOSYGNALÓW

A b s t r a c t

Machines and devices control can be held using keyboard, joystick, touch interface, gesture recognition interface or speech. Completely different control form is biosignals use, such as electromyogram, electrooculogram or electroencephalogram. In the article presented the controller construction of electro-pneumatic servo drive, which control is backed up by biosignals generated by activity patterns in muscles, brain and eye.

Keywords: *wireless network*, *biosignals*, *electro-pneumatic servo drive*

S t r e s z c z e n i e

Sterowanie maszyn i urządzeń może odbywać się za pomocą klawiatury, joysticka, interfejsu dotykowego, interfejsu rozpoznawania gestów czy też mowy. Zupełnie odmienną formą sterowania jest wykorzystanie biosygnałów takich jak elektromiogram, elektrookulogram czy też elektroencefalogram. W artykule przedstawiono budowę sterownika serwonapędu elektropneumatycznego, którego sterowanie wsparte jest biosygnałami.

Słowa kluczowe: *sieci bezprzewodowe*, *biosygnały*, *serwonapęd elektropneumatyczny*

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1. Introduction

Remote control of machines and devices contributes to significantly safety increase of their service, since operator doesn't have to be directly at operated machine. One way to implement remote control is the use of radio waves, which are commonly used in wireless computer networks. These networks at the turn of the last few years gained more popularity. Constant their development causes that they are faster, safer, more reliable and due to easiness of installation becomes increasingly common in the industry [1].

Operator communication with the machine can be held using keyboard, joystick, touch interface, gesture recognition interface or speech, which additionally can be backed up by biopotentials, such as electromyogram, electrooculogram or electroencephalogram. These biosignals measured by electrodes placed on operator head it is possible to use to speed up the reaction to appearing incidents.

For the purposes to present possibility of using wireless network WiFi and biosignals in electro-pneumatic servo drive control a laboratory position was built and written communication application between the operator and servomechanism.

2. Communication in computer networks

The information exchange between network devices is held according to closely of defined principles called protocols. Their task is to define the format and structure of sent message, ways of information and errors exchange as well as to establish and finish connections. Protocols don't usually describe how to carry determined function out, therefore implementation of given protocol is independent from specific technology.

Network communications interacts with many different protocols, which forms a connected group of protocols presented as the stack (see Fig.1) [2]. There are two basic models of the network. Model TCP/IP (protocol model) and OSI model (reference model).

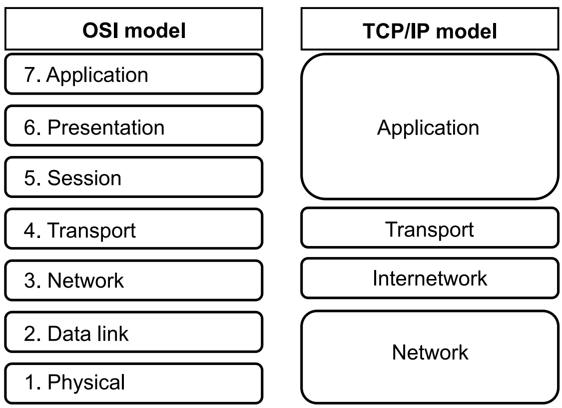

Fig. 1. OSI model and TCP/IP model

Rys. 1. Model odniesienia i model protokołów

Model TCP/IP is regarded as the model of Internet network. It defines four layers responsible for correct communication network. Access layer to the network is responsible for control of physical devices and media forming the network. Internet layer determines the best route of packages in the network, however transport layer deals with the communication between different devices in different networks. The last (application layer) presents as well as reads data from the user. OSI model consisting of seven layers provides a list of functions and services, which may occur in every layer, by what has a significant participation in the development of other protocols [2], [3].

Communication process takes place in two directions. Sending data to network consist on passing information from the application layer to access layer in network, however receipt data is an opposite process.

2.1. Wireless communication

In the access layer to network of the TCP/IP model it is possible to distinguish three types of media transmission, which connect the terminal equipment and provide data transmission between them. These are metal cables (copper), fibre-optic cables and wireless communication. Due to easy access to the medium transmission as well as easiness of structure and networks expansions based on wireless medium communication is more widely used in the communication. One of popular access wireless methods to the computer network is WLAN (Wireless Local Area Network). These networks are in accordance with the 802.11 group of standards, which describes rules for the first and second layer OSI model. Frequency range of the radio waves used by the standard doesn't require the concession; therefore it is possible to use this standard without special licenses. In the first standard version, transmission underwent in 2.4 GHz band and in infrared at wavelength from 850 nm to 950 nm. However, the infrared didn't entertain due to numerous restrictions of this transmission type. Currently also 5 GHz band is used.

2.2. Network protocols

Exchange of data fragments via network between determined terminal devices takes place through Internet layers in addressing, encapsulation, routing and decapsulation of transmitted data process. Commonly used protocol in the network layer is Internet Protocol, in 4 version as well as 6 newest version, which is successively implemented. Moreover, in the network layer implement are protocols such as: IPX (Internetwork Packet Exchange), Apple Talk or connectionless service CLNS/DECNet network.

IP protocol is a connectionless protocol; therefore communication with its use is fast and flexible. Unfortunately information exchange can be unreliable, since protocol doesn't assure that packages will reach the addressee, will be in the correct order, won't be fragmented or doubled. Reliability transmission task is held on layers of the high level in network model.

2.3. Transport protocols

Transport layer task is to provide simultaneous work in multiple different applications by placing in one transmission channel of messages parts from different applications. This task is performed in the segmentation and multiplexing data process.

Depending on requirements which are put to transmit data, two basic transmission protocols are distinguished: TCP and UDP. The TCP Protocol is a protocol which guarantees reliable provision of data to the recipient by tracking transmitted data, receipt confirmation of data and repetition of lost data. It is interconnection protocol, what means that before transmitted data by the network, connection is established between the communicating devices. Second protocol which is simpler under construction is UDP protocol. This protocol above all performs less function from TCP. It is a protocol faster than TCP, doesn’t require confirmations as well as doesn’t provide lost data for the retransmission, by which doesn’t ensure reliability. It’s characterized by a small additional data mark-up. As for applying mentioned protocols, where reliability of the data transmission is required the TCP protocol is applied. In case of less sensitive data, where applications are tolerant to loss of small data amounts, UDP protocol is applied [2, 4, 5].

2.4. Application

An application layer is responsible for providing interface between the user of network device and data network. In this layer it is possible to distinguish two types of the software: applications and services. Services of the application layer are usually transparent for the user and are responsible for connecting the application with network and sending data. Application provides interface for the user, reads and presents data as well as initiates the process of data transmission by network.

Protocols of the application layer define the way of data exchange between applications and services, which are started on devices participating in the communication. They carry it out by determining the type and format of exchanged message as well as by determining the way of sending and receiving message. In this layer a different types of protocols function, defined by standards as well as data formats. Telnet can be an example of the application, service and protocol, which is an interface for user (application), program supporting connections for the transmission files (service) and interchange standard of network communications (protocol) [2].

3. Biosignals

Biosignals source can be bioelectric signals, bioresistances, bioaccoustic, biomechanical and biochemical. Measuring impedance tissue during microelectricities transmission it is possible to obtain bioresistances signals, which are a source of information about structure and tissue composition. Using bioaccoustic signals it is possible to obtain information about phenomenon, such as blood flow in vessels or heart. Measuring movement or pressure biomechanical it is possible to obtain biomechanical signals, however biochemical signal source is a measurement on living tissues or laboratory samples. Bioelectric signals are generated by nerve cells or muscle and are often used for examinations in medicine. Most commonly potentials used are electromyogram (EMG), electrooculogram (EOG) and electroencephalogram (EEG). Electromyogram uses electrical signals originating from working muscles, electrooculogram it’s a record of appearing tension course, between front (positive) and back (negative) eyeball pole, and electroencephalogram records electric activity of the brain [7]. Table 1 shows the frequency and amplitude of the biosignals [8].

Table 1

Frequency and amplitude of the biosignals

Type	Frequency (Hz)	Amplitude
EMG	0.01–15000	strongly dependent on the activity of muscle < 10 μV – 100 mV
EOG	0.1–50	< 1 μV – 10 mV
EEG	0.01–150	< 1 μV – 1 mV

4. Controller of the electro-pneumatic servo drive

The controller of servomechanism was built based on the ALIX.1D microcomputer board, module for data acquisition MicroDAQ USB-1208FS, WiFi Ubiquiti XR2 card as well as biosignals reader NIA – Neural Impulse Actuator (Fig. 2).

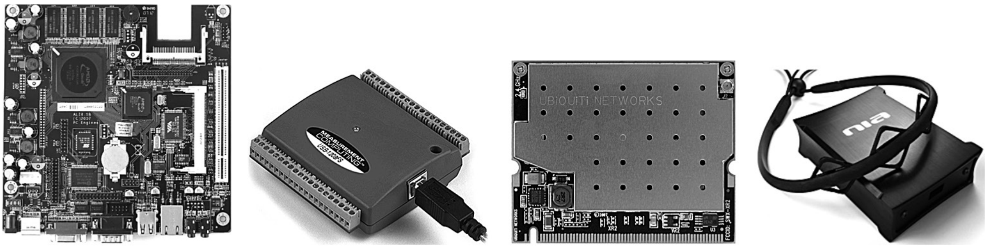

Fig. 2. Elements used for the controller construction. From left: ALIX 1D microcomputer board, module of the acquisition data MicroDAQ USB-1208FS, wireless card Ubiquiti XR2, Neural Impulse Actuator – biosignals reader

Rys. 2. Elementy wykorzystane do budowy sterownika. Od lewej: płyta mikrokomputera ALIX 1D, moduł akwizycji danych MicroDAQ USB-1208FS, karta bezprzewodowa Ubiquiti XR2, Neural Impulse Actuator – czytnik biosygnałów

Microcomputer board ALIX.1D is equipped with AMD Geode 500 MHz processor and 256 MB memory RAM. Powered with voltage 12 V and characterized by small conscription of the electricity, row of 0.4 to 0.5 A. The task of board is to connect wireless card, input output port and application for the controller. On the memory card was installed operating system Windows XP, because equipping board meets the minimal requirements for system as well as in this system doesn’t have problems with detection installed additional devices and with drivers to it [6].

As input/output port for the driver was chosen module for the data acquisition MicroDAQ USB-1208FS. This system has 4 analog inputs in the symmetrical system about resolution of 12 bits and 8 inputs in the asymmetrical system about resolution of 11 bits. In the asymmetrical system is a possibility of voltage measurement ±10 V, while in the symmetric system ±20 V. For generation output signals are available 2 analog outputs about resolutions of 12 bits. Output voltage range amounts to 0–4.096 V at maximum load current 15 mA. This module is connected to the driver board by USB interface.

Communication with the operator computer is ensured by Ubiquiti XR2 card. The card is equipped with connector MMCX, which provides better connection card – pigtail than popular in miniPCI cards UFL connectors. Card supports standard 802.11b and 802.11g, has a high output power (26 dB) and receiver sensitivity up to -95 dB. Depending on used aerial inside the premises it is possible to obtain up to 200 m, however on the open area about 50 km.

For the driver communication with operator were written two applications: one for controller and second for operator. The application of controller performs role of the service. Its task is to adjust the actuator position as well as to listen and wait for connection on chosen port from the operator. In case of connection detection the service starts to collect (set position value) and send data (current position value). When operator finishes the connection, application again turns into the state of listening and waiting. Application operator task is to collect data from the user and their presentation as well as control signals process from the biosignals reader.

Biosignals reader has own application, which can be configure so that based on determined biopotentials values the appropriate control signals were generated, e.g. pressing bottom on the keyboard. In program it is possible to exploit three biopotentials: electromyogram, electrooculogram and electroencephalogram, which use Alpha and Beta waves. Biosignals are measured using three electrodes located on elastic band, which are placed on operator's forehead.

Controller program and for the operator were written using LabVIEW software, which allows to write program using protocols, such as TCP, UDP, Bluetooth or IrDA [6]. Due to ensuring small delays during data transmission, UDP was chosen as the transport protocol. For communication created are two connections: one to send the set value of actuator location and second to send current value of actuator location.

The controller role is to receive from operator by wireless network the actuator set point and to make appropriate adjustment position values process based on measured current value of the actuator location.

On the test-stand was used rodless pneumatic actuator of the Festo Company, magnetostrictional position converter of the Balluff Company, which is used to measurement current value of the actuator location and proportioned valve 5/3 of the Festo Company (Fig. 3). Signal coming from the converter position is a voltage signal from the scope 0–10 V, however the control signal for valve is a voltage about 0–10 V values. Module for data acquisition it is possible to measure voltage ±20 V, however the maximum voltage which can be generate is 4.096 V. Therefore, in the controller preamplifier is applied, built on LM358 system. It's operational amplifier system of the rail-to-rail type. This type of amplifier was applied due to asymmetrical supply controller voltage, which amounts +24 V. In order to match the microcomputer supply voltage, which amounts 12 V, a converter impulse LM2576 was used.

Controller based on measured and set value establishes the actuator position. For position adjuster of the actuator location a popular PID regulator was applied, which setting was conducted by Ziegler-Nichols method.

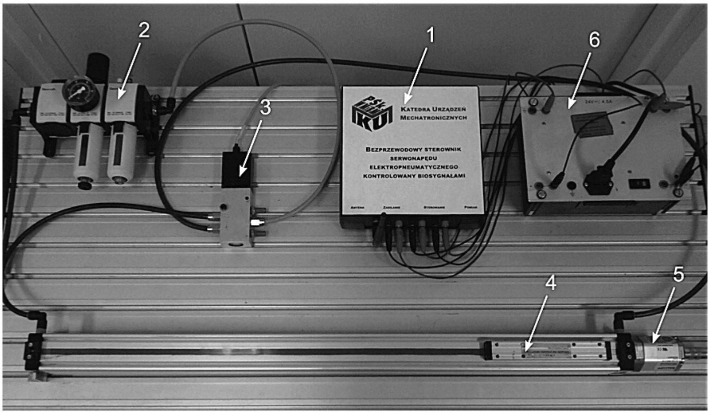

Fig. 3. Test-stand: 1 – Wireless controller of the servomechanism, 2 – Air preparation unit, 3 – Valve, 4 – Actuator, 5 – Location converter, 6 – Power supply

Rys. 3. Stanowisko badawcze: 1 – bezprzewodowy sterownik serwomechanizmu, 2 – zespół przygotowania powietrza, 3 – zawór, 4 – siłownik, 5 – przetwornik położenia, 6 – zasilanie

5. Results

On the laboratory position studied the wireless network use in servomechanism electro-pneumatic control as well as biosignals application in the control process. In experiment used all available biosignals from the application level: muscle tension measurement, eyeball movement measurement as well as Alpha and Beta waves. To determined signal levels, they were assigned to simulation pressing appropriate buttons on the keyboard: Page Up – increase actuator position value, Page Down – reduce actuator position value, End – press emergency stop button. As a result of conducted experiments stated that electromyogram signals use, e.g. through adjustment of the pressure tongue strength to palate or clenching teeth with bigger or smaller strength gives the best effects to generate control signal. Unfortunately during examinations it was very hard to precisely determine the demanded actuator position. Remaining biosignals, due to difficulty of appropriate level obtaining, didn’t allow for simple determining the actuator position. As a result of conducted experiment in the laboratory position obtained characterizations of the servomechanism electro-pneumatic work, which were presented on Fig. 4.

It results from the analysis of above graphs that there is a delay between set signal value 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.

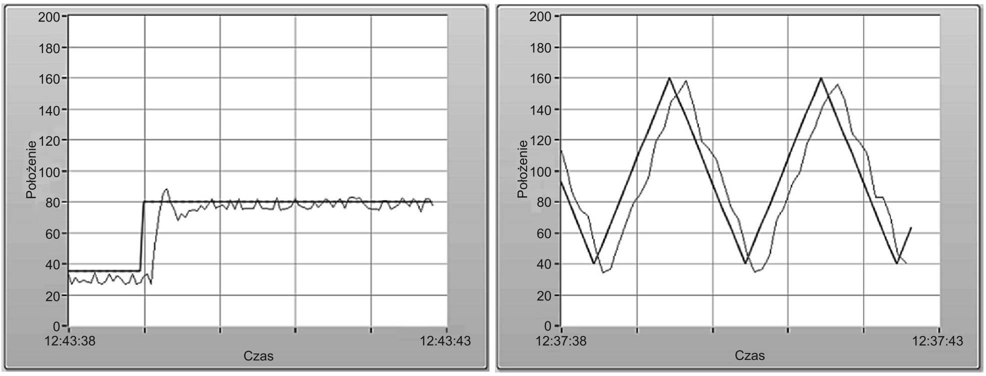

Fig. 4. Manual and automatic control of the electro-pneumatic servo drive

Rys. 4. Sterowanie ręczne i automatyczne serwonapędu elektropneumatycznego

In spite of the fact that defect in the studied controller is impose of delays between the control and read signal, what disqualifies it as the adjuster, it is possible to use it for simple control of the servo drive in systems not-requiring big precision and in places dangerous to very operator of the servomechanism.

6. Conclusions

Wireless communication in spite of its limitations, such as susceptibility to disruptions or delays in transmission gives us great possibilities of use where it isn't possible to apply cable networks. Wireless control can significantly improve security of the operator as well as reduce structure costs of the network infrastructure. Conducted simulations in the laboratory position confirm that it is possible to use the wireless computer network WiFi without obstacles to communication of the operator with the remote device. Examinations also confirm that in the process it is possible to use control biosignals of different types. Although a precise determination of the actuator position was difficult, this type of control can be used in accelerating operator response on the existing reaction. An example can be pressing the emergency device stop button.

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