Information Technology in Medical Diagnostics II

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Some technical propositions for electromyographical human interface device

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ABSTRACT: Recognition of gestures is an actual and important problem. This technology can be applied in various fields of human activity: management of computers and household appliances, creating a natural human-machine interfaces for the deaf, the manipulation of three-dimensional models of objects, virtual reality applications, management of quadrocopters and exoskeletons. The purpose is to analyze of existing technical solutions of the implementation of human interface device, identification of deficiencies of these devices, as well as offer some technical solutions to address these deficiencies. The work is based on the method of surface electromyography. Technical solution for the implementation of the device, based on the detection of electromyographic signal, taking into account the position of the object in space, is proposed, structural and functional schemes are developed. This device is supposed to implement on the base of Wi-Fi technology network. To reduce the energy consumption it is necessary to use energy-efficient software algorithms. The proposed implementation of the human interface device has no shortcomings of analyzed analogues: a wired connection between the segments, the presence of a reference electrode. The prospect of research is optimization of the gesture recognition algorithms, testing of these algorithms, studying of the possibility of simultaneous repetition of movements, definition of the limits of speed and number of degrees of freedom of movement.

1 INTRODUCTION

Human-Computer Interaction (HCI) is an interdisciplinary scientific field that studies the interaction between people and machines. The subject of HCI is the study, planning and development of methods of human interaction with the machine, where a personal computer, a large-scale computer system, a process control system, etc. can act as a machine (Dix et al. 2014). Interaction is understood as any communication between a person and a machine. One of the methods of HCI, which has become widespread in recent years, is interaction based on human gestures (Sanna et al. 2012).

Gestures are movements which are a non-verbal way of information conveying. Movement of fingers, hands, head, shoulders, facial expressions: all of these movements are gestures. With the help of gestures, a person can transmit an independent informational unit, supplement the verbal series, convey feelings, etc. Usually gestures are divided into static (perceived simultaneously) and dynamic (perceived at some time), having a certain interpretation in manual alphabets and contactless man-machine interfaces. In HCI gestures are used to transfer information to a computer, which can then be used to identify a person, control a computer, an aircraft, a game character, etc.

In the literature, the task of recognition of hand gestures is interpreted by different ways, such as calculation of the position of the palm, shoulders and fingertips, identifying of the configuration and the path of the hand, and so on. In the present work, under the task of recognition of the gestures of the hand, we will understand the following three subtasks:

1. recognition of the arm position in three-dimensional space;
2. recognition of the static gesture of the hand according to the reference configurations;
3. recognition of dynamic gestures along the trajectory of the hand movement.

The hand gesture recognition system is a collection of computer technologies and mathematical algorithms that allow to solve the task of recognition of a certain group of gestures of the hand. The recognition of gestures can be applied in such areas of human activity, for example:

1. Computer and home appliances management.

In the computer application for each arm configuration, the specific command is mapped. The person shows the gesture, the system recognizes the configuration of the hand and sends the corresponding command to the computer. The position of the palm is compared with the position of the mouse cursor on the screen. Movements of the hand lead to cursor movements. The mouse click commands are matched to different hand configurations.

2. Creation of natural human-machine interfaces for deaf-mutes.

The gesture recognition system can be used to enter text into the computer with the help of hand gestures, which for the deaf and dumb people is simpler and more natural than entering text using the computer keyboard. According to the World Federation of the Deaf, around 72 million deaf people live around the world who communicate in sign language. Words and sentences in sign language are shown by means of gestures of hands, fingers and facial expressions.

Unlike people who have become deaf as a result of an accident or for reasons of illness, people who are deaf since birth prefer a sign language to an ordinary text. It is easier for them to accept and show gestures than to read or type text on the keyboard of a computer or phone. The difficulty of communication also arises when a deaf person communicates with the hearing person, when the hearing person does not know the sign language (Wójcik & Smolarz 2017).

3. Manipulation of three-dimensional models of objects.

To date, to work with three-dimensional models usually use a computer mouse, which is not very convenient for this task. Having three-dimensional coordinates of the hand, you can create a HCI system, which will allow you to manage models in all directions of three-dimensional space.

4. Applications of virtual reality.

By supplementing the gesture recognition system with devices, for example, with stereoscopic glasses, you can create virtual reality applications where the user can "touch" virtual objects.

The list can be supplemented with systems that accompany the rehabilitation of patients (Kinect Rehabilitation with Biofeedback), gaming applications (Controller-free gaming with Xbox 360 + Kinect), etc. Some of these applications are already used in different devices and programs (Samsung Smart TV 2013 with Smart Interaction), and some of them are still at the research stage.

5. Control of quadrocopters (Myo Gesture Control Armband Thalmic Labs) and exoskeleton (neurobotics).

Human Interface Device (HID) is a class of devices intended for interaction with a person, including devices such as a keyboard, mouse, game controller and others.

At the moment, there are many fundamentally different systems that realize the movement of human limbs: systems using surface electromyography, systems that record motion with video cameras and analyze the resulting images (Kinect (Kastaniotis et al. 2015)), systems based on radiation and infrared light (Multitouch Table (Ch'ng 2012)), systems using different resistive sensors sewn into clothing (Project FineSkills (Xing et al. 2012)).

However, all existing implementations of the human-device interface are rather cumbersome. For image analysis systems and systems based on the Doppler effect, you must be at a fixed distance from the device. Systems based on surface myography have an advantage among known systems, since they perform a direct analysis of the work of muscles.

The aim of the work is to analyze the existing technical solutions of HID devices, identify the shortcomings of these devices, and also offer some technical solutions to address these shortcomings.

2 EXPERIMENTAL RESEARCH

Existing devices based on surface myography are made in the form of various bracelets designed to be worn on the arm. A typical solution of this bracelet is the radially placed blocks, each of which is a segment of the bracelet. Each segment contains electromyographic (EMG) electrodes and a biopotential amplifier. The main segment, in addition to the main components, also contains analytical and control units. Some systems, in conjunction with the registration of EMG signals, use spatial sensor data, such as a gyroscope and an accelerometer.

When constructing a human-computer interface based on surface myography, there are several problems that are difficult to solve under conditions of miniaturization of the user device. The main problem is the implementation of the connection of individual segments of the bracelet with the main one, in which the analysis and recognition of movement take place. The implementation of communication between the units on the basis of a wired network leads to a problem of cumbersomeness due to a large number of connectors, as a result—a decreasing of the reliability and comfort of using the device. It is possible to implement a connection based on wireless technologies, this eliminates the problem of a large number of wired connections, but requires a separate power supply for each segment (Bobick et al. 1999, Shotton et al. 2011, Pugeault & Bowden 2011).

Nowadays, there are several implementations of human-computer interface based on EMG. Nokia Research develops a HID based on four standard EMG sensors containing two rectangular electrodes located across the muscle fibers, as well as a reference electrode located at the site of minimal muscle activity (Figure 1) (Desney et al. 2009). The method proposed by Microsoft uses ten point electrodes placed around the arm in two rows (Figure 2) (Zhang

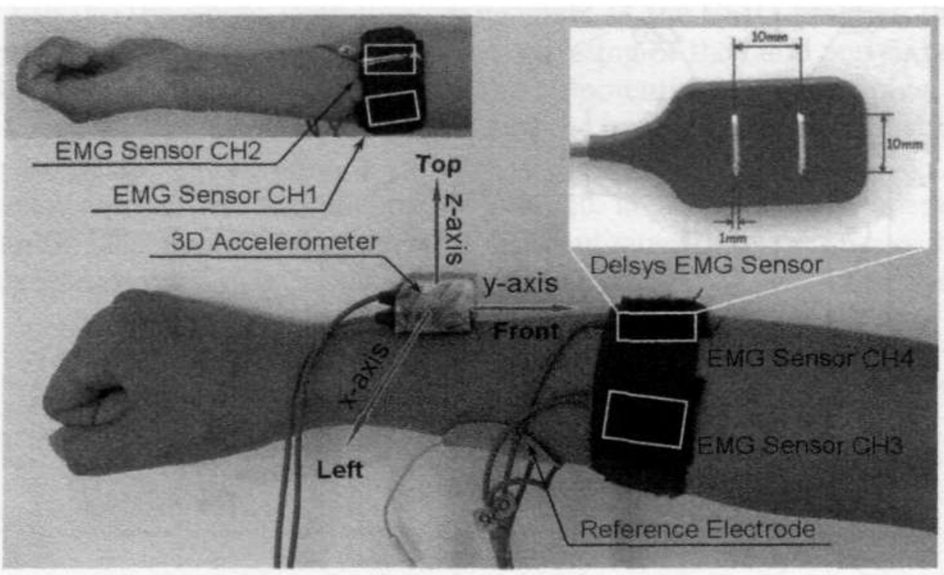

Figure 1. The location of the electrodes in the research of Nokia Research.

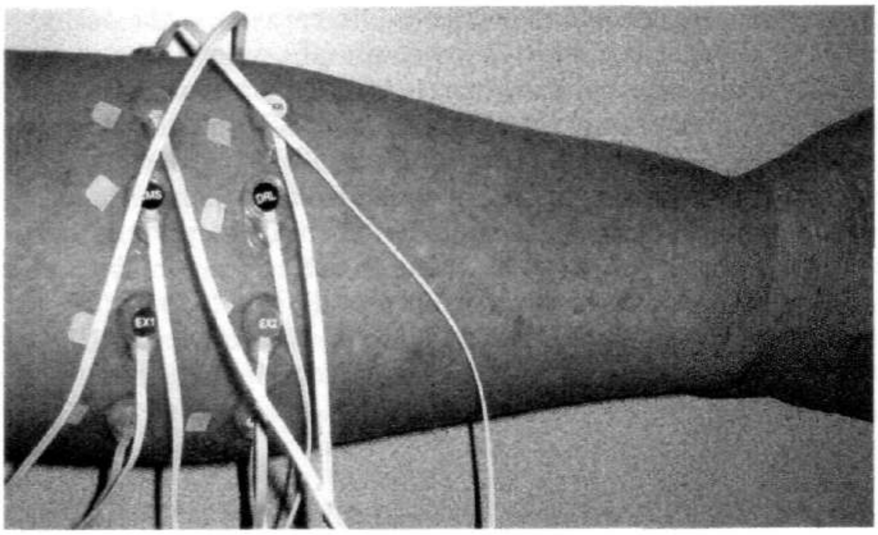

Figure 2. The location of electrodes in research by Microsoft.

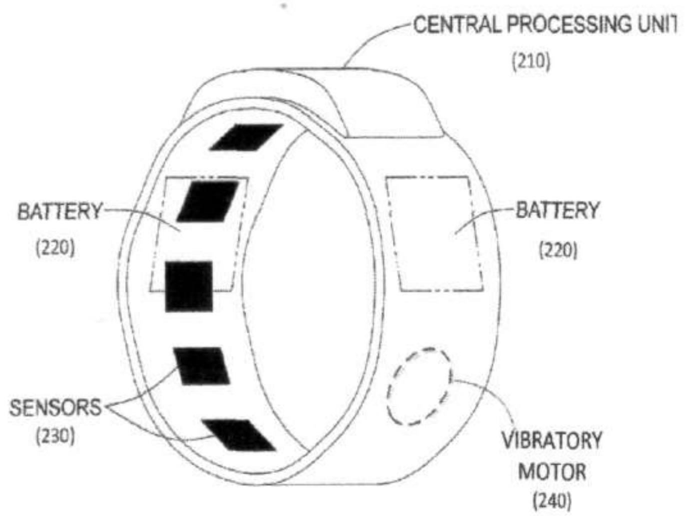

Figure 3. The MYO device from Thalmic Labs Inc.

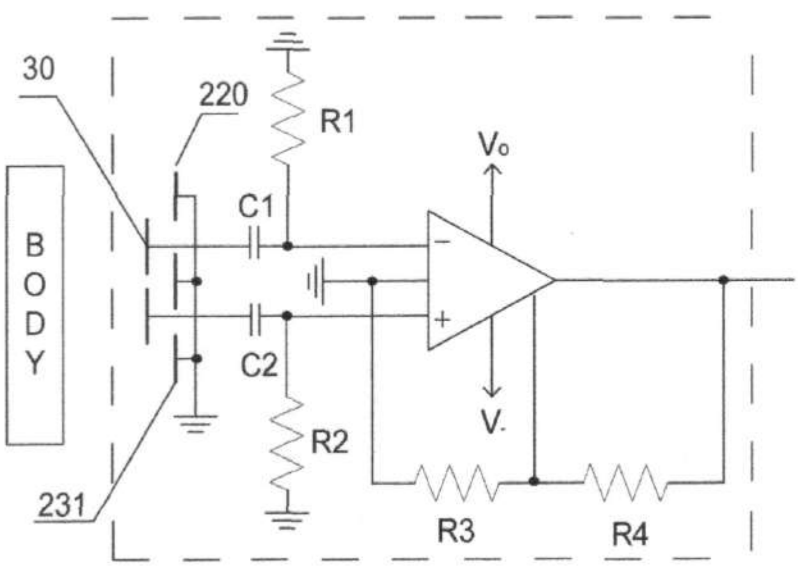

Figure 4. The biopotential amplifier in the MYO device.

et al. 2009). The HID device offered by the developers of Thalmic Labs Inc. (Lake et al. 2014) uses shielded EMG sensors arranged in a row and grouped into a bracelet (Fig. 3). The circuit solution (Figure 4) from Thalmic Labs Inc solves the electrode-skin resistance problem and does not require the presence of a reference electrode.

Shortcomings of the described devices: a wired connection between segments and a controlled device; and presence of a remote reference electrode in the implementations of devices of Microsoft and Nokia researches.

3 RESULTS AND DISCUSSION

A device based on the registration of the EMG signal by the method of surface myography taking into account the position of the object in space is proposed. Functionally the device is constructed as follows: EMG signal is recorded with the help of surface myography, then amplified and converted into a digital code, according to the specified conditions, calculated numerical parameters are transmitted to the main segment, then the data collected from all segments are analyzed, and if the gesture is recognized, information about this is transmitted to the controlled device. The functional diagram of the device being developed is shown in Figure 5.

It is supposed to implement the device in the form of a bracelet consisting of eight equal segments. Each segment has two rectangular EMG electrodes, an instrumentation amplifier, a microprocessor and a battery. The level of the EMG signal of the muscles of the upper limbs of a person during registration with the help of surface myography lies in the range from 20 μV to 2 mV. The instrumentation amplifier has a bias voltage of less than 20 μV with amplification of the order of 1,000. The microprocessor contains an ADC with a sampling frequency of 2,000 Hz and supports the operating in the wireless networks of the selected standard.

Communication between segments is carried out by combining them into a wireless network. Given that there are more than two segments (network clients), and bandwidth is more than 400 kB/s, only two standard networks are suitable for this purpose—IEEE 802.11 (Wi-Fi) and ISO/IEC 18092 (NFC).

This device proposes to implement a network based on Wi-Fi technology. To reduce energy consumption, it is necessary to use energy-saving software algorithms.

The block diagram of the device being developed is shown in Figure 6.

The device is realized in the form of a bracelet consisting of eight segments. The number of segments is selected, based on the anatomical structure of the hand and the functions performed by the muscles of the arm. Each segment has a status indication and a capacitive button.

To start working with the device, the bracelet is put on the user's arm and is located about 2/3 from the hand to the elbow. With this arrangement of the EMG bracelet, the electrodes will be placed on the muscles responsible for the operating of the hand and fingers.

The EMG signal, which will be recorded by the biopotential extraction units, will contain information about the operation of the fingers and the hand, in accordance with the muscle on which the motor unit is located.

When muscle activity is detected, the bracelet goes into an active mode of operating and the microcontroller of each segment calculates a set of quantitative characteristics of muscle activity. The calculated data from all segments is collected in the main segment for analysis. Based on

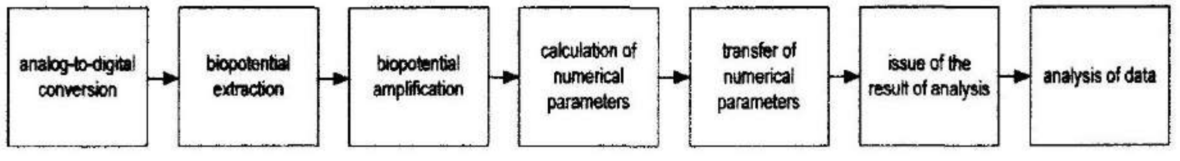

Figure 5. Functional diagram of the offered HID device.

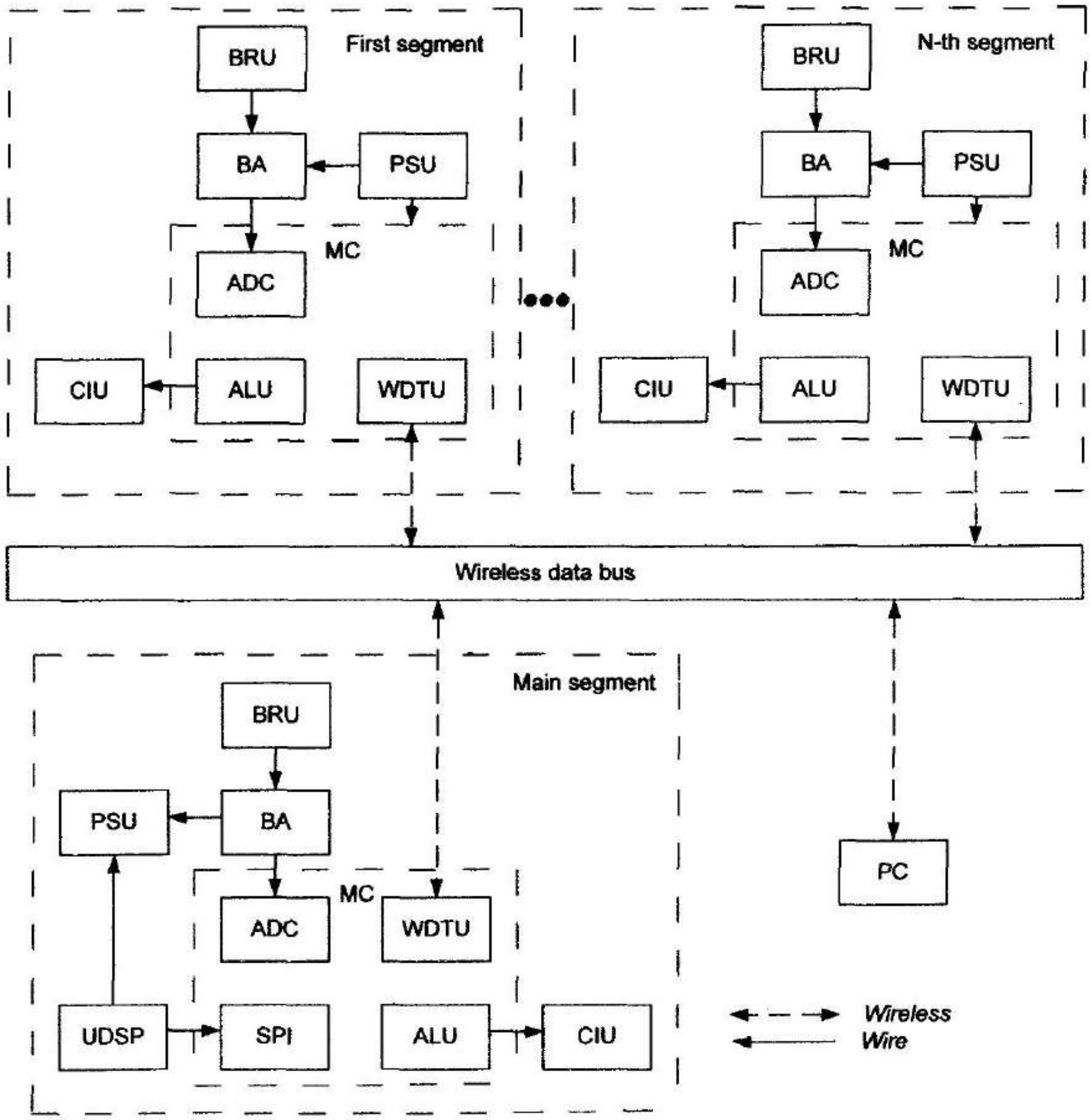

Figure 6. Structural diagram of the developed HID-device (BRU – biopotential registration unit, CIU- control and indication unit, BA – biopotential amplifier, PSU – power supply unit, ADC – analog-to-digital converter, ALU – arithmetic logic unit, WDTU – wireless data transmission unit, SPI – serial peripheral interface, UDSP – the unit for determining the spatial position, PC – personal computer, MC – microcontroller).

mathematical models of various gestures for these characteristics and spatial position data, the microcontroller of the main segment determines the type of gesture and sends a control signal in the form of a code to a computer or a controlled device. On the managed device (computer), the receiving program (driver) performs the actions corresponding to this code. After determining the gesture and transferring its code to the controlled device (computer), the bracelet goes into standby mode to save energy. Since there are no wired connections between the bracelet segments, each of them requires its own battery. The current consumption of each segment does not exceed 250 mA, therefore, to maintain the device up to 8 hours, a battery with a capacity of 800 mAh is selected. Given that the segments are eight and the average charging time of one battery is about 3 hours, it will take every 3 hours to connect the next segment to the network or connect 8 chargers at once. Both options are inconvenient and impractical, so the principle of wireless charging is chosen based on the inductive coupling between the charger and the segments.

4 CONCLUSIONS

The modern technical solutions for constructing HID devices are analyzed, shortcomings such as wire communication between segments and a controlled device, and the presence of a remote reference electrode are revealed. Some technical solutions are proposed to eliminate these shortcomings. Thus, structural and functional diagrams have been developed for a device based on recording of the EMG signal by the surface myography method taking into account the position of the object in space. It is supposed to implement the device in the form of a bracelet consisting of eight equal segments. Each segment has two rectangular EMG electrodes, an instrumentation amplifier, a microprocessor and a battery. This device proposes to implement a network based on Wi-Fi technology.

In the proposed HID device there are no shortcomings of the analogues described above: wire communication between segments, the presence of a reference electrode.

The future of the work is optimization of motion recognition algorithms, testing of these algorithms, investigation of the possibility of recognition of synchronous repetition of movements, determination of the speed limits and the number of degrees of freedom of movement.

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For many centuries, mankind has tried to learn about his health. Initially, during the pre-technological period, he could only rely on his senses. Then there were simple tools to help the senses. The breakthrough was turned out to be the discovery of X-rays, which gave insight into the human body. Contemporary medical diagnostics are increasingly supported by information technology, which for example offers a very thorough analysis of the tissue image or the pathology differentiation. It also offers possibilities for very early preventive diagnosis. Under the influence of information technology, 'traditional' diagnostic techniques and new ones are changing. More and more often the same methods can be used for both medical and technical diagnostics. In addition, methodologies are developed that are inspired by the functioning of living organisms.

Information Technology in Medical Diagnostics II is the second volume in a series showing the latest advances in information technologies directly or indirectly applied to medical diagnostics. Unlike the previous book, this volume does not contain closed chapters, but rather extended versions of presentations made during two conferences: XLVIII International Scientific and Practical Conference 'Application of Lasers in Medicine and Biology' (Kharkov, Ukraine) and the International Scientific Internet conference 'Computer graphics and image processing' (Vinnitsa, Ukriane), both held in May 2018.

Information Technology in Medical Diagnostics II links technological to medical and biological issues, and will be valuable to academics and professionals interested in medical diagnostics and IT.

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