EXPERIMENTAL HUMAN-INTERFACE DEVICE BASED ON INERTIAL AND MUSCLE ACTIVITY SENSORS

O.V. Derhunov, S.V. Shenhur

Abstract: The report presents overview of the developed prototype of the experimental human-interface device based on inertial and muscle activity sensors. The described device includes measuring channels of muscle activity and tilt angles and Bluetooth module for wireless data exchange.

The paper shows the general device overview, its structural schematic, measuring channels description, electronic component base nomenclature, circuit diagram of muscle activity measuring channel.

Key-words: human-interface device, accelerometer, measurement, muscle activity sensor.

1. Introduction

Nowadays, at the present state of information technologies, the design of human-interface devices (HID) is one of the important engineering tasks. A wide variety of tasks in different fields is solved with the help of HIDs: from heavy industry and robotics to entertainment. Generally, computer mice, trackballs, and joysticks are used as an input device in computerized systems. Minimization of electronic components and development of high-capacitive power batteries led to appearance of "next" generation HIDs. They are based on the inertial and muscle activity sensors, and are more suitable for some tasks then traditional devices. HIDs based on inertial sensors operate with information about their orientation and relative movements in space. The ones based on the muscle activity sensors record signals of the contractions of operator's muscles and, depending on that basis form control signals. Such principles are applied in a wide variety of areas: from prosthetics in medicine and computer control peripherals, to development of robotic manipulators and exoskeletons. There are several commercial examples of similar devices [1], though they have not become widespread. Also, from the research engineer perspective, they are all a "black box", what makes difficult to analyze the work of different ways of informative features extraction. Therefore, the development of an experimental human-interface device based on inertial and muscle activity sensors is an important task.

The technical task is to develop the experimental prototype of a computer input device with measuring channels of muscle activity, tilt angles of the device (pitch and roll), and with the ability for wireless data exchange.

2. Generalized structure of the device

The device is mounted on the wrist of the operator and records the position and activity of his hand. The main parts of the prototype are: the measuring channel (MC) of muscle activity based on electromyography principles [2], measuring channels of the tilt angles based on accelerometer and gyro, microcontroller (MCU), and Bluetooth wireless connectivity module (fig.1).

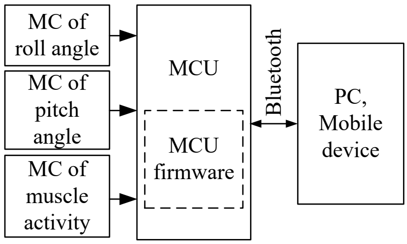

Fig. 1. The structural schematic of the experimental HID

3. Measuring channels

The measuring channel [3] of muscle activity (fig. 2) consists of the sensor in the form of three electrodes (1) located on the elastic cuff and the signal conditioning unit, which includes instrumentation amplifier AD-8226 [4] (2), rectifier (3), a low-path filter (4), and output amplifier (5).

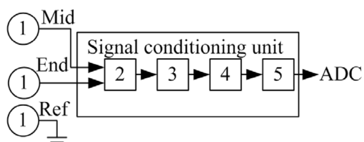

Fig. 2. The structural schematic of the muscle activity MC

Electrodes are connected to a wrist in 3 points: to the “end” of muscle, to the “middle” of it, and to the opposite side of an arm for reference voltage level (fig. 3).

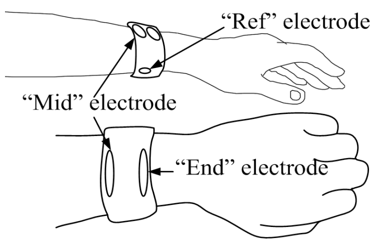

Fig. 3. The schematic diagram of electrode connection

The circuit diagram of one separate measuring channel of muscle activity is presented on figure 4.

The purpose of the signal conditioning unit is to select the informative characteristics of the signal and to scale them to the analog-digital converter input range. The output signal is passed to the microcontroller analog line.

To ensure detection of multiple gestures several measuring channels of muscle activity are needed. One channel can confidently detect 3 different gestures. With two channels and simple detection algorithm it is possible to determine 4 gestures. Using versatile algorithms may allow detecting even more separate gestures.

Tilt angles measurement is performed in a way of a combination of instantaneous values of linear acceleration and angular velocities with the help of sensor fusion techniques.

In the designed HID, primary information about the position of the device in space is obtained via micro-electro-mechanical (MEMS) inertial sensor MPU6050 [5]. It includes accelerometer and gyroscope sensors that allow finding linear acceleration and angular velocity for three coordinate axes during motion. The sensor has digital serial interface I2C and can be easily connected to any modern MCU. Signals from the sensor are processed in the microcontroller in the following way:

• on the beginning of a measurement cycle MCU gets 6 values from the MPU6060 sensor:

a_x – a projection of acceleration vector on X axis,
a_y – a projection on Y axis,
a_z – a projection on Z axis,
ω_x – the rotation speed around X axis,
ω_y – the rotation speed around Y axis,
ω_z – the rotation speed around Z axis;

• tilt angles determination based on the accelerometer indications:

$$\alpha_a = \operatorname{atan2}\left(\frac{a_x}{\sqrt{a_y^2 + a_z^2}}\right) - \frac{\pi}{2}, \qquad (1)$$

$$\beta_a = -\left[\operatorname{atan2}\left(\frac{a_y}{\sqrt{a_x^2 + a_z^2}}\right) - \frac{\pi}{2}\right]; \qquad (2)$$

• tilt angles determination based on gyroscope indications:

$$\alpha_g[i] = \alpha_g[i\text{-}1] + \omega_y\,dt, \qquad (3)$$

$$\beta_g[i] = \beta_g[i\text{-}1] + \omega_x\,dt; \qquad (4)$$

• tilt angles measurement errors estimation and their subsequent minimization with the complementary filter application:

$$\alpha_f = (1\text{-}d)\,\alpha_g + d\alpha_a, \qquad (5)$$

$$\beta_f = (1\text{-}d)\,\beta_g + d\beta_a, \qquad (6)$$

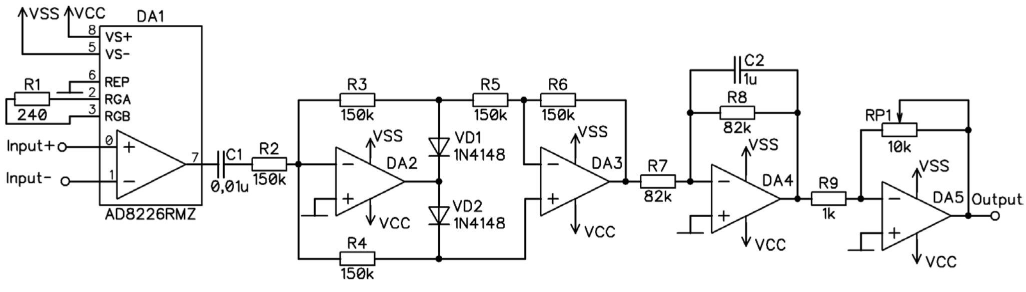

Fig. 4. The circuit diagram of the muscle activity MC

$$d \in [0{,}01;\ 0{,}1]; \qquad (7)$$

• final measurement result processing and registration.

After the aggregation, the measurement results are being processed by a particular algorithm, and control commands are formed for the controlled device. The commands are transmitted via the Bluetooth module HC-05. With the special firmware HC-05 is visible to any compatible electronic device (PC or mobile) as general HID: mouse or gamepad, etc. Also, it allows raw measurement data transmission for further analysis on PC. It may help in development of versatile algorithm for informative features extraction.

4. Conclusions

The described results can be used in the development of the modern input devices and control systems for computerized complexes in various fields. It is especially important due to the rapid development of virtual reality technologies, remote medical operations, remote robotics, etc.

5. References

[1] https://www.myo.com/ accessed on May 28th, 2018

[2] **Shapiro B.E., Preston D.C.** *Electromyography and neuromuscular disorders* / B.E. Shapiro, D.C. Shapiro. – Woburn: Butterworth-Heinemann, 2005:1. – 658 p.

[3] http://www.advancertechnologies.com/p/muscle-sensor-v3.html, accessed on May 28th, 2018

[4] *Wide Supply Range, Rail-to-Rail Output Instrumentation Amplifier AD8226* – Data Sheet – Analog Devices, 2012. – 28 p.

[5] *PU-6000 and MPU-6050* – Product Specification – InvenSense Inc., 2013. – 52 p.

Information about the Authors:

Oleksii Volodymyrovych Derhunov, MSc in Metrology and information-measurement systems (2012), PhD in Computer systems and components (2016). Scientific field and interests: Digital electronics, computer engineering, measurement systems, data processing. Workplace: National Aviation University, Institute of information-diagnostics systems, Department of Information-measurement systems, Mailing address: Ukraine, Kyiv, 03058, 1 Kosmonavta Komarova ave.

Web address: *ivs.nau.edu.ua,*

e-mail address: dergunov.av@gmail.com.

Svitlana Vitaliivna Shenhur, MSc in Metrology and information-measurement systems (2008), PhD in Standardization, certification and metrological assurance (2013). Scientific field and interests: methods and means for measurement data analysis, measurement systems. Workplace: National Aviation University, Institute of information-diagnostics systems, Department of Information-measurement systems, Mailing address: Ukraine, Kyiv, 03058, 1 Kosmonavta Komarova ave.

Web address: *ivs.nau.edu.ua,*

e-mail address: shengur.s@gmail.com.