BITALINO USE AND APLICATIONS FOR HEALTH, EDUCATION, HOME AUTOMATION AND INDUSTRY

César Páris[1], Jorge Barbosa[1], Emanuel Ferreira[1], Anabela Gomes[1,2]
[1]Engineering Institute of Polytechnic of Coimbra
Rua Pedro Nunes, Quinta da Nora, 3030-199 Coimbra, Portugal
[2]Centre for Informatics and Systems – University of Coimbra
Pólo II - Pinhal de Marrocos, 3030-290 Coimbra, PORTUGAL

ABSTRACT

This paper aims to present a project, developed in the context of higher education, where Bitalino was used. It explains its working mode, its practical applications and possible uses in the development of applications for several purposes. This project includes the development of several practical applications for each of the components of Bitalino. Their interaction possibilities with the user and the enhancement of utilization examples for their various sensors will also be explained.
Based on the same microcontroller used in the Arduino Uno R3, the ATmega328P, the base kit of Bitalino is composed of several modules that results in a low-cost vital sign reading platform. These modules, linked together, serve as a platform for the different sensors and actuators that we can connect to Bitalino. The Bitalino MCU module is responsible for converting the analog signals from the sensors into digital signals so that they can then be processed by the software and used by the applications. This conversion is done using its own firmware; which is recorded on the integrated circuit of the MCU and it is upgradeable. Included with the kit is also a pair of electrodes that allow the sensors to read the body's electrical activity so that we can interpret the same signals (muscular, cardiac or others). The software included with Bitalino is named Open Signals and allows the acquisition and visualization of the different signals acquired by the different sensors processed by the MCU.
A relatively simple application has been created that allows the viewing of sample signals acquisition from all the MCU inputs. This same application was later expanded to contain mini applications that react directly to one or more specific modules. In order to exemplify the operation and utility of each of the sensors, mini applications have been created that use or combine different sensors/actuators.
As the applications were being developed, there were ideas of tools and applications for expanding Bitalino, so we considered that there is potential for this work to be continued with immense applications in the area of health, people with special needs or care, education, home automation and industry. This paper suggests some of these possibilities.

Keywords: Bitalino; Health; Education; Home automation; Industry

1. INTRODUCTION

This paper has as a goal to present a project including the Bitalino, namely its operation, its practical applications and possible uses in the scope of application development for people with special needs or care. During the project several practical applications were developed for each of the components of Bitalino in order to show their possibilities of interaction with the user and to enhance the investigation for practical cases of use of their various sensors. The project had a research component in addition to the development of applications due to the fact that the Bitalino project, which is not well known, be supplied only with signal visualization software and with relatively basic practical components about its use.
The applications of Bitalino are immense and varied. For instance, in the area of physiological computing [14, 24], defined as the field, within physical computing, that deals with the study and development of systems that sense and react to the human body. The recording of vital signs in the practice of sports [23], such as swimming [21] and other areas [16] the muscle fatigue detection [3]; the devices activation through the muscles [20, 8]; the control of robots [11]; the home health care or rehabilitation [11, 15]; the detection of human emotions [6, 7] the control of body parts [5] or the ergonomics aspects [22] are another applications areas of Bitalino.

2. THE BITALINO

Developed as a low-cost vital sign reading platform, Bitalino is a Portuguese project developed inspired by other similar equipment such as Arduino and Raspberry PI ([1].
Based on the same microcontroller used in the Arduino Uno R3, the ATmega328P, the Bitalino base kit consists of several modules, the main ones being the microcontroller or MCU module, the power module and the Bluetooth module. These modules, linked together, serve as a platform for the different sensors that we can connect to Bitalino and whose applications will serve as a basis for this work. The Bitalino MCU is responsible for converting the analog signals from the sensors into digital signals so that they can then be processed by the software and used by the applications. This conversion is done using its own firmware, which is recorded on the integrated circuit of the MCU, and it is upgradeable. Connection to Bitalino is normally done wirelessly via Bluetooth, but a physical connection can be made to the device through the UART port on the device. Included with the kit there are also a pair of electrodes that allow the sensors to read the body's electrical activity so that we can interpret the same signals, be they muscular, cardiac or others. These electrodes use a gel base that improves the electrical conduction between the electrode and the area of the skin where it is placed. The software included with Bitalino is named OpenSignals and allows the acquisition and visualization of the different signals acquired by the different sensors processed by the MCU. This software is written in Python language and can also be used in the commercial version of Bitalino, the BioPlux.
The board used in this project, the Bitalino plugged version, includes the following components: MCU + Bluetooth + Power Board; EMG sensor, a muscle activity sensor; ECG sensor - an electrocardiogram sensor; EDA sensor – an electrodermal

sensor; ACC sensor – a motion sensor; LUX sensor – a light sensor; LED - this actuator consists only of a Light-Emitting Diode; Electrodes; RJ22 connection cables and 500mAh lithium battery.

2.1 Sensors

One of the sensors that accompany Bitalino is the ECG an electrocardiogram sensor that allows detecting the electrical differentials of the heart cells. This sensor allows the acquisition of signal by placing a pair of electrodes near the heart, or in another area of the body such as the palms. It can be used for heart rate monitoring, physical activity measurement, portable ECG, and other interactions with the computer. Due to its small size, this type of sensor allows an easy integration into mobile devices. The possibility of using it for bionic prosthesis applications (an amputated person can, using a muscle, control the movement of it), Robotics, Videogames and biomedical applications are immense.

Another sensor of interest is the LUX sensor that allows detecting variations of luminosity. It can be used as a heart rate sensor, LCD brightness adjustment for ambient light, cameras and optical synchronization. This sensor, which is not included in the initial package of Bitalino, allows detecting variations in ambient temperature, body temperature and various applications such as ambient analysis, temperature protection systems (Alarms, heaters, etc.), CPU temperature and others. This sensor does not require any type of calibration to present a good precision and has already been calibrated to Celsius degree scale.

The EDA sensor allows the detection of variations in the resistance of the epidermis. These changes in resistance allow the user to detect changes in the emotional state and can be used to detect nerve stimuli, emotional state feedback or biomedical information. The process of working of this sensor boils down to the fact that our perspiration, responsible for regulating temperature and other nerve activities, changes the skin state. This change allows us to convert into numerical values this variation that we can use later in the way that is most convenient for us. According to its datasheet, the most suitable zone to carry out this measurement is in the palm of the hands and the soles of the feet.

The ACC sensor has a chip that allows detecting the acceleration movement on the 3 axes, X, Y and Z. This value allows the user to use the retrieved data to detect movement together on all 3 axes or individually. The uses of this sensor will be diverse: Activity Monitor, Motion Detection, Tilt Detection, Image Stabilization, Sports Equipment, Hard Disk Protection, among others. The sensor that integrates by default the Plugged kit, presents only connections for the Z axis, therefore, a change was made to the hardware so that we can use the remaining X and Y axes.

2.2 Actuators

The LED actuator is a simple LED that can be turned on/off by Bitalino according to the need for visual feedback, and can have varied applications essentially for optical synchronization and visual feedback.

The BUTTON actuator is a button that can be used to activate/deactivate functions of Bitalino, and may have varied applications at the level of Event Trigger and Function Activator.

The BUZZER actuator, not included in Bitalino package, provides an audible signal when powered. It is activated by providing a signal through its I/O port. Possible applications focus primarily on the level of audible feedback and synchronization mainly in terms of Alarms and Audible Notifications.

The TOUCH SENSOR actuator functions as a touch sensor. It is an alternative to the mechanical button so we can activate and deactivate it with a simple touch on its surface. It can have lots of applications to replace a traditional button, while also being waterproof.

2.3 Applications of Bitalino Sensors/actuators

Considering the set of actuators and sensors available in Bitalino we think in the usefulness of developing a set of applications, using them. In order to do this, we have investigated the literature in order to provide useful indications for the development of applications of some of their sensors. We found applications of the ECG sensor in bionic prostheses, especially in the area of robotics, for the detection of muscular pain [13], for gesture recognition [4] or in terms of biometry [9]. Another possible use of ECG is for new ways of interacting with the computer, adapting the difficulty of an activity, such as a game, depending on the sample of the heartbeat [19].

The ACC sensor is used to detect slope variations on different devices including modern smartphones. This sensor can also be used as triggering for applications, for example by activating a trigger if there is movement in the sensor on one of the axes. Some examples of applications of this sensor include: Image rotation, Vibration sensor or Hard disk protection (impact detection). This sensor is also used in the medical field in detecting patient posture [2] or as a pedometer for step counting [10, 18].

The LUX sensor is well known for its application in modern smartphones in order to control the brightness of an LCD according to ambient light, thus helping to conserve energy. This is a method widely used to conserve battery life in modern smartphones since in low light environments we do not need to have a brightness as high as in outdoors [25, 26].

There are also some studies related to the EDA sensor within the scope of detection of the emotional states and the nervous system of a given individual [17].

3. Developed applications

3.1 Sensors/Actuators personalization

In order to test the operation of the digital inputs and outputs, a custom version of an integrated LED actuator was built using an old computer game controller. This modified command allows both acting on Bitalino and receiving visual feedback directly on the button used. This change was necessary due to the fact that we initially did not have any input actuator available, since the button was only supplied later. Since each Bitalino digital connector has one input and one output on the same connector, only a single cable has to be used in order to interact with it, making use of both connections simultaneously. The custom actuator simulates the circuit shown in the following Figure 1. Another necessary change was the inclusion in the ACC sensor of the connecting pins to the X and Y-axes. By default, this sensor is only ready to connect to the Z axis, since the inclusion of the other axes implies the use of 2 analog channels in addition to main one used, in a total of 3 channels only for a sensor.

Figure 1- Old computer game controller

In order to test the operation of the digital inputs and outputs, a custom version of an integrated LED actuator was built using an old computer game controller. This modified command allows both acting on Bitalino and receiving visual feedback directly on the button used. This change was necessary due to the fact that we initially did not have any input actuator available, since the button was only supplied later. Since each Bitalino digital connector has one input and one output on the same connector, only a single cable has to be used in order to interact with it, making use of both connections simultaneously. The custom actuator simulates the circuit shown in the following figure. Another necessary change was the inclusion in the ACC sensor of the connecting pins to the X and Y-axes. By default, this sensor is only ready to connect to the Z axis, since the inclusion of the other axes implies the use of 2 analog channels in addition to main one used, in a total of 3 channels only for a sensor.

3.2 New Aplications

Bitalino comes with a test application and visualization of the signal of its sensors. In addition to this initial tool there are also some APIs programmed in different languages in order to assist users in developing applications for Bitalino, using the programming language that best suits their needs or with which they feel more at ease. These API's have small applications, however they are rather rudimentary and should only be used as a reference to start development. The development platform chosen for this project was Visual Studio 2013 and the C# language. The C# library was used as the basis for our application, available on the Bitalino website, which allows us to connect to the device and receive sample values from it. Using this library, several applications were created to demonstrate the operation of the various sensors and the motherboard.
A relatively simple application was created that allows us to visualize a sample acquisition of signals from all the inputs of the MCU. After an initial study using the application of tests an application providing us with a visual feedback of their use/performance was created. This application was later expanded to contain mini-applications that act directly on one or more specific modules. Figure 2 illustrates some aspects of this application.

Figure 2 – Signal Acquisitions Application

In order to exemplify the operation of each of the sensors, mini applications have been created that use or combine different sensors/actuators. The TMP Application (Figure 3) aims to detect the ambient temperature using the TMP sensor. The software uses its conversion form to convert the sampling value to degrees centigrade and shows this value to the user, such as the sampled (RAW) value without conversion. We can also define the same channel where we want to connect the sensor in question. The Sensors/Actuators used were the TMP Sensor (Port A1 to A6) and the LED or BUZZER (Port O1).

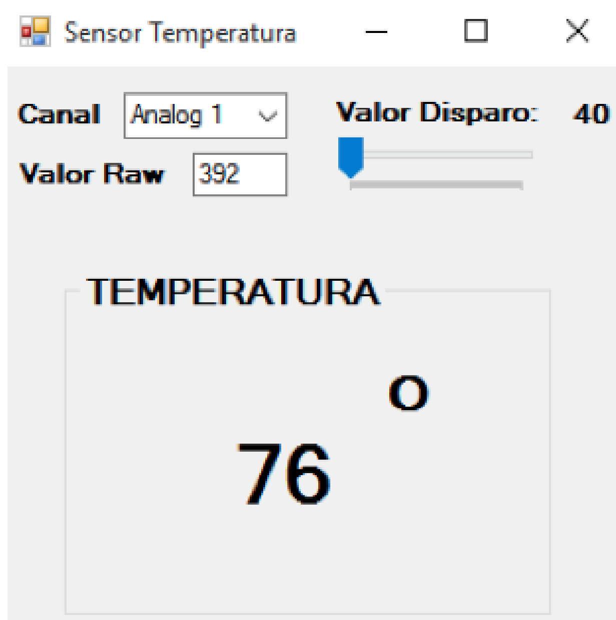

Figure 3 – Temperature Sensor Application

The App EMG Trigger Application (Figure 4) is intended to use the EMG sensor to simulate a keystroke, in this case the left and right SHIFT. The application, calibrating a value as the default value, verifies if the value of the sensor sampling exceeds the value previously set to be triggered and act on it.

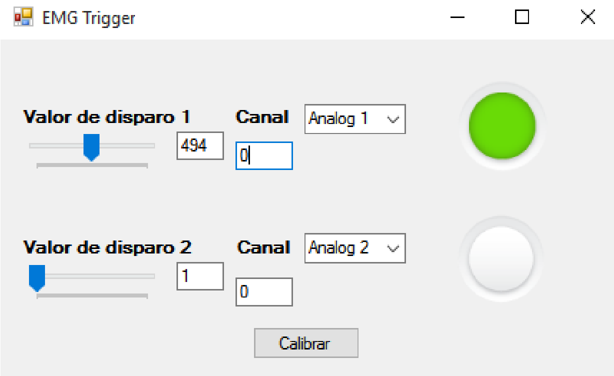

Figure 4 – EMG Trigger Application

In order to exemplify the operation of this sensor we use a game (Figure 5) that will receive the introduction of two SHIFT keys. The program sends the keys to the Windows active window, in other words, the window that is in the foreground. We can set the steady value of the trigger or calibrate it. This (stable calibration) value will allow the application to assume it as a base in order to check for possible oscillations detected by the sensor. In the case of calibration the application checks the average value at rest and uses this value as the basis for the trigger.

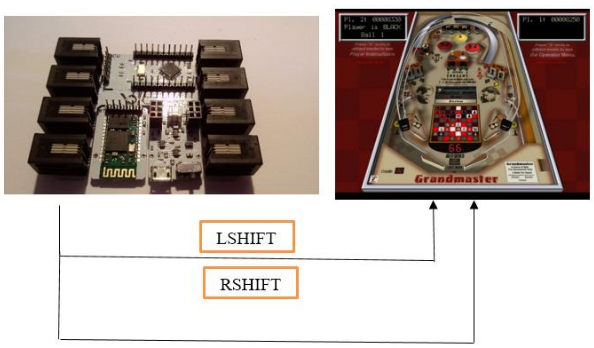

Figure 5 – Game using the MG Trigger Application

The BPM (Figure 6) application allows using the ECG sensor to detect heartbeats. The application calculates the heart rate using the sample value. Each beat is recorded and also used to activate the digital output. One of the difficulties of using the sensor is its tendency to noise in the signal, which hinders not only its acquisition but also its use. For this it is important that filters are applied to the signal in order to correct this noise and improve its quality.

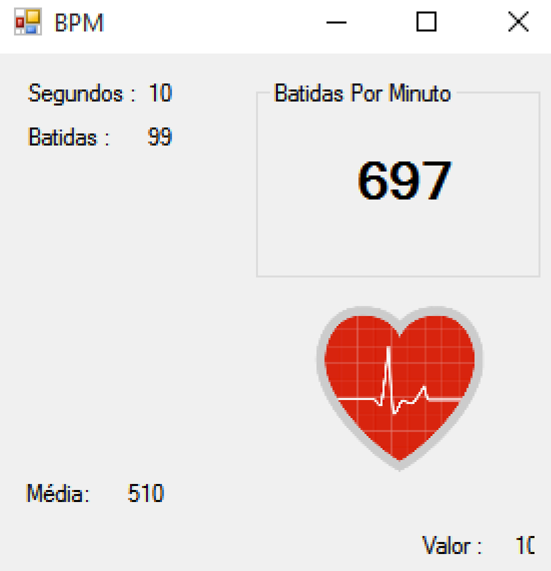

Figure 6 –BPM Aplication

The ACC Cube Application (Figure 7) application is another developed application allowing us to view values for moving the accelerometer sensor. If the sensor does not change, it only shows the values related to the Z-axis. If we have the extra connection, we can see the values related to the 3 following axes, X, Y and Z. The application in addition to converting the values into G force also allows visualizing the rotation of a 3D Cube in function of the movement of the sensor in the X, Y and Z-axes. Before carrying out the conversion we can calibrate the sensor indicating which values it will assume to be flat on a surface, using the button created for this purpose. This value will be assumed by the cube as a reference value, that is, as being levelled.

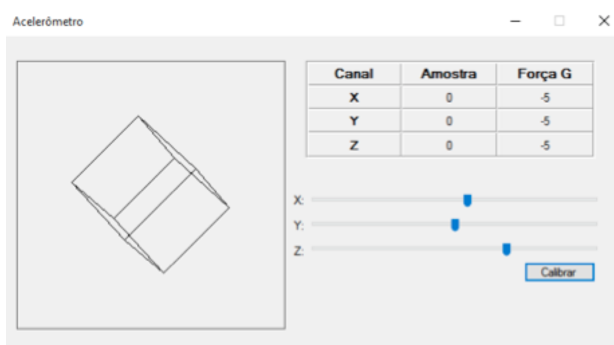

Figure 7 – ACC cube Application

The LUX Application (Figure 8) allows interacting with the light sensor. This sensor allows detecting brightness variations and, using this application, we can pass this variation of luminosity to an actuator to give us feedback.

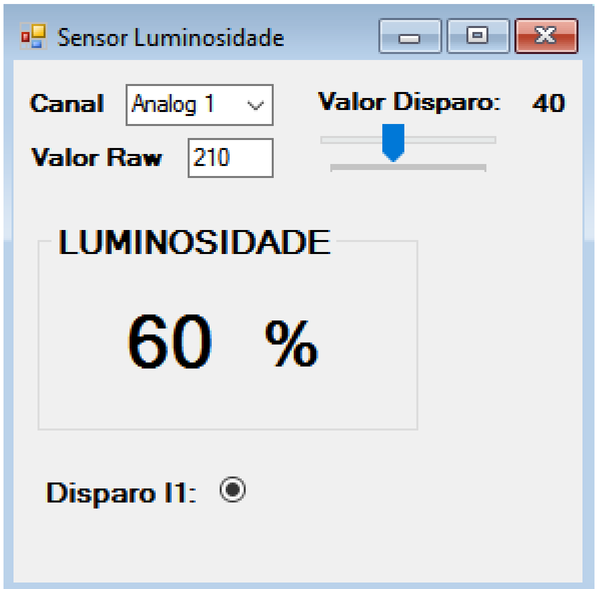

Figure 8 – LUX (Luminosity) Application

8. CONCLUSIONS

This document reports a preliminary work with Bitalino including some physical changes to its different components, in order to overcome some limitations in terms of signal reading. In order to expand the scope of work, components were also integrated that were not part of the initially acquired package, in order to exploit its versatility in relation to similar products, such as Arduino, using some components originally intended for it.

In order to exemplify the operation and utility of each of the sensors, mini applications have been created that use or combine different sensors/actuators. The Temperature Application aims to detect the environment temperature using the TMP sensor. The EMG Trigger Application uses the EMG (muscle activity sensor) sensor to simulate a keystroke, in this case the left and right shift. The BPM Application allows the use of the ECG (electrocardiogram) sensor to detect heartbeats. The ACC Cube App application shows the values related to accelerometer sensor movements. The LUX Application allows the interaction with the light sensor to detect variations in brightness.

A new application starting to be developed intended to allow the detection of variations in the resistance of the epidermis, indicating changes in the emotional state, to be used to detect nerve stimuli and give feedback regarding certain emotional states. However, a larger project is currently being planned, which, using Bitalino, works in the area of medical rehabilitation, especially using therapies that include muscle reflexes. Physiotherapy is a health area that aims to intervene on human movement in all of its expression forms, with the purpose of preserving, maintaining, promoting, developing and restoring the integrity of organs, systems and functions. One of the problems for those who need the care of this area is that only in clinical settings can they have professional assistance. Thus, the idea of this project is to create an application that can monitor and guide the patients, throughout the exercises required for their rehabilitation, in a professional way, and outside of hospitals or offices.

Given the great versatility of its components it is considered that Bitalino has many more possible uses than those that have been presented and developed. As the applications were being developed, there were possible ideas of tools and applications for Bitalino, so we considered that there is potential for this work to be continued with immense applications in the area of health, education and home automation.

9. REFERENCES

[1] A. Alves, H. Silva, A. Lourenço, and A. Fred, "Bittalino: A biosignal acquisition system based on the arduino", In Proc. of BIODEVICES (2013), pp. 261–264.

[2] M. Aung et al., "The Automatic Detection of Chronic Pain-Related Expression: Requirements, Challenges and the Multimodal EmoPain Dataset," In Proc. of IEEE Transactions on Affective Computing, Vol. 7, No. 4, pp. 435-451, Oct.-Dec. 1 2016. doi: 10.1109/TAFFC.2015.2462830

[3] P. Bhat and A. Gupta, "A novel approach to detect localized muscle fatigue during isometric exercises," In Proc. of 2016 IEEE 13th International Conference on Wearable and Implantable Body Sensor Networks (BSN), San Francisco, CA, 2016, pp. 224-229. doi: 10.1109/BSN.2016.7516264

[4] S. Benatti et al., "A Versatile Embedded Platform for EMG Acquisition and Gesture Recognition," In Proc. of IEEE Transactions on Biomedical Circuits and Systems, Vol. 9, No. 5, pp. 620-630, Oct. 2015. doi: 10.1109/TBCAS.2015.2476555

[5] A. Bernardino, Y. Rybarczyk and J. Barata, "Versatility of human body control through low-cost electromyographic interface", In Proc. of the Int'l Conf. on Applications of Computer Engineering (ACE), (OCTOBER), 2014, pp. 87–92. http://doi.org/10.13140/2.1.1454.3686

[6] T. Bosse, C. Gerritsen, J. de Man and M. Stam, "Inducing Anxiety through Video Material. Communications in Computer and Information Science", 434 PART I, 2014, pp. 301–306. http://doi.org/10.1007/978-3-319-07857-1_53

[7] T. Bosse, C. Gerritsen, J. De Man and J. Treur, "Learning emotion regulation strategies: A cognitive agent model", In Proc. of 2013 IEEE/WIC/ACM International Conference on Intelligent Agent Technology, IAT 2013, Vol. 2, pp. 245–252. http://doi.org/10.1109/WI-IAT.2013.116

[8] B. Caramiaux, M. Donnarumma and A. Tanaka, "Understanding gesture expressivity through muscle sensing", ACM Transactions on Computer-Human Interaction (TOCHI), Vol. 21, No. 6, 2015, pp. 31-47.

[9] A. Fratini, M. Sansone, P. Bifulco and M. Cesarelli, "Individual identification via electrocardiogram analysis", Biomed Eng Online, Vol. 14, No. 78, 2015. doi: 10.1186/s12938-015-0072-y

[10] R. Fostera, L. Lanningham-Foster, C. Manohara, K. Shelly, S. McCrady, L. Nyssea, K. Kaufman, D. Padgettb, J. Levine, "Precision and accuracy of an ankle-worn accelerometer-based pedometer in step counting and energy expenditure", 2005. http://dx.doi.org/10.1016/j.ypmed.2005.07.006

[11] B. Gamecho, J. Guerreiro, A. Alves, A. Lourenço, H. Silva, L. Gardeazabal, J. Abascal and A. Fred, "Evaluation of a Context-Aware Application for Mobile Robot Control Mediated by Physiological Data: The ToBITas Case Study, Ubiquitous Computing and Ambient Intelligence", Personalisation and User Adapted Services, Vol. 8867 of the series Lecture Notes in Computer Science, pp. 147-154.

[12] B. Gamecho, H. Silva, J. Guerreiro, L. Gardeazabal and J. Abascal, "A Context-Aware Application to Increase Elderly Users Compliance with Physical Rehabilitation Exercises at Home via Animatronic Biofeedback", Journal of Medical Systems, pp. 39-135, 2015.

[13] M. Geisser, “Surface electromyography and low back pain. Biofeedback”, Vol. 35, No 1, pp. 13–16, 2007.

[14] J. Guerreiro, R. Martins, H. Silva, A. Lourenço and A. Fred, “BITalino: A Multimodal Platform for Physiological Computing”, In Proc. of the 10th ICINCO Conf, 2013, pp. 500–506. http://doi.org/10.5220/0004594105000506

[15] T. Y. Han, S. D. Min and Y. Nam, “A Real-Time Sleep Monitoring System with a Smartphone”, In Proc. of 9th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, Blumenau, 2015, pp. 458-461. doi: 10.1109/IMIS.2015.69

[16] H. Ibrahim, S. Ewais and S. Chatterjee S., “A Novel, Low-Cost NeuroIS Prototype for Supporting Bio Signals Experimentation Based on BITalino”, In: Davis F., Riedl R., vom Brocke J., Léger PM., Randolph A. (eds) Information Systems and Neuroscience. Lecture Notes in Information Systems and Organisation, Vol 10. Springer, Cham, 2015.

[17] Y. B. Lee, S. W. Yoon, C. K. Lee and M. H. Lee, “Wearable EDA sensor gloves using conducting fabric and embedded system”, In Proc. of Annual International Conference of the IEEE Engineering in Medicine and Biology, 2006, pp. 6785–6788. http://doi.org/10.1109/IEMBS.2006.260947

[18] C. Nolan et al., “Pedometer Step Count Targets During Pulmonary Rehabilitation in COPD: A Randomized Controlled Trial”, American Journal of Respiratory and Crital Care Medicine, 2016.

[19] D. Nguyen, “Improving game experience using dynamic difficulty adjustment based on physiological signals”, Master Thesis, Technical University of Denmark, DTU Compute, 2014.

[20] G. Oliver, "Relationship between gluteal muscle activation and upper extremity kinematics and kinetics in softball position players", Medical & biological engineering & computing Vol. 52, No 3, 2014, pp. 265-270.

[21] A. Pinto et al., "Electrocardiography, electromyography, and accelerometry signals collected with BITalino while swimming: Device assembly and preliminary results," IN Proc. Of IEEE 12th International Conference on Intelligent Computer Communication and Processing (ICCP), Cluj-Napoca, 2016, pp. 37-41. doi: 10.1109/ICCP.2016.7737119

[22] M. Reinvee and M. Pääsuke, “Overview of Contemporary Low-cost sEMG Hardware for Applications in Human Factors and Ergonomics”, In Proc. of the Human Factors and Ergonomics Society Annual Meeting, Vol. 60, No 1, pp. 408 - 412

[23] J. Rodrigues, A. Belguinha and P. Cardoso, “Processing sports acquired information from a tracking system”, In Proc. of 19th Portuguese Conference on Pattern Recognition, Lisboa, Portugal, 2013.

[24] H. Silva, A. Fred and R. Martins, "Biosignals for Everyone," In Proc. of IEEE Pervasive Computing, Vol. 13, No. 4, pp. 64-71, Oct.-Dec. 2014. doi: 10.1109/MPRV.2014.61

[25] P. Vaghefinazari, et al. "Object recognition in low-lux and high-lux conditions." U.S. Patent No. 9, pp. 302-621. 5 Apr. 2016.

[26] L. Wang et al., "Lighting system design based on a sensor network for energy savings in large industrial buildings", Energy and buildings Vol. 105, 2015, pp. 226-235.