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Leap Motion, Myo Armband and Kinect v2 Low-Cost Motion Sensors in the Internet of Things, Controlled by Raspberry Pi 3 and Arduino UNO

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Abstract:- The Internet of Things (IoT) is a constantly developing phenomenon, which involves an abundance of intelligent devices in schools, healthcare institutions and homes. IoT includes sensors sensing temperature, humidity, pressure, as well as many other quantities. This paper discusses the following issues: is it appropriate and if so, what devices to use to implement motion sensors in IoT. The article also opens the issue of interconnecting motion sensors – Leap Motion, Kinect v2 and Myo Armband with an Arduino UNO microcontroller and a Raspberry Pi 3 microprocessor.

***Keywords**:- Arduino UNO; Leap Motion; Kinect V2; Myo Armband; Raspberry Pi 3.*

I. INTRODUCTION

The Internet of things (IoT) is a network of remotely controlled, significantly automated intelligent devices. There is an ever-growing number of devices, connectible to the IoT, thus there is a constantly growing demand for their reliability and intelligence. Analysts expect IoT to be one of the fundamental changes in the field of information and communication technology in the following decade [1]. A market survey conducted in 2013 estimated the number of connected devices to be 4 billion in 2010, 15 billion in 2012 and expected 80 billion devices to be involved with IoT [2]. IoT includes various motion sensors or light sensors. In our previous work, we focused on utilizing Kinect V2, Leap Motion and Myo Armband sensors [3]. We connected the aforementioned sensors to a sensor network to make the recognition of the users' gestures and movements more reliable. We implemented the communication of these low-cost sensors using the Unreal, Unity 3D and LabVIEW programming environments. Kinect V2 and Leap Motion monitor the infrared spectrum; however, these sensors are often disturbed by the environment and other devices or reflections, leading to errors and inaccuracy [4]. Our research proved that these inaccuracies may be eliminated by synchronizing these sensors with a Myo Armband sensor, monitoring the user's movements and hand gestures using electromyography sensors, accelerometers and gyroscopes [5]. Our goal is to integrate the sensors into the IoT to allow the user to benefit from the IoT and the added value of accurate movement and gesture recognition. The aforementioned sensors allow such an IoT-integration using the Raspberry Pi 3 and Arduino UNO prototyping platforms.

II. INTERNET OF THINGS

IoT is a mutual interconnection of all devices on Earth, reacting to real-world signals mostly in an autonomous and automated fashion, making our lives more comfortable. IoT is a "network of devices", capable of capturing information from the real world, such as temperature, presence or absence of people or objects, etc. [6]. IoT includes various sensors, such as light sensors, ultrasound sensors and even sensors, which may be used to protect the users' safety and property, sensors aimed at CO_2 or natural gas level metering. Devices connected to the IoT include intelligent refrigerators, climate control devices, intelligent power sockets and other devices operating in households or directly on the users' bodies. Based on the sensed values, servomotors, climate control elements and other devices are being controlled.

III. LOW-COST MOTION SENSORS

There is a wide range of low-cost motion sensors available for integration into an intelligent household, connected to the IoT. Low-cost sensors are often used in healthcare, where they assist the process of rehabilitation, in case of patients having issues with their locomotor system [7].

A. Kinect v2

Kinect v2 is an open source camera sensor, designed as part of the Microsoft Xbox game console. By using an adapter, it is compatible with multiple platforms. In Figure 1 is shown sensing body and hand recognition by Kinect v2.

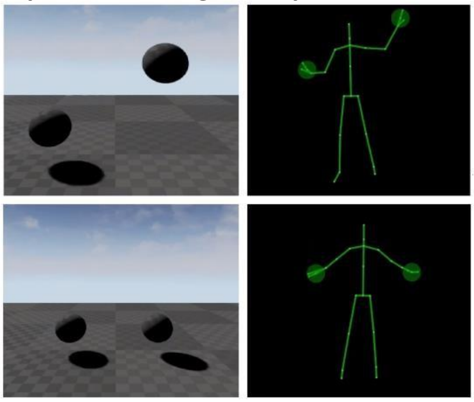

Fig 1:- Kinect in Unreal Engine test

- Monitors 26 joints of up to 6 persons,
- 1080p, 30 fps, HD RGB camera,
- Sensing depth: 512x424/16bpp , 50cm-450cm,
- USB 3.0 [8].

This sensor is a combination of a new camera, an RGB camera and a microphone array of four microphones. With the microphone array, the device is capable of identifying the speaker and focusing on the speaker's voice. Kinect v2 can distinguish whether the person is sitting or standing and can identify simple hand gestures: the "lasso", in which the user sticks out his index and middle fingers, the "fist" and the "open hand" gestures [9].

B. Leap Motion

The Leap Motion sensor was developed to monitor depth, but - unlike Kinect v2 - it has no microphone nor RGB camera [10]. This sensor is aimed at high-precision hand monitoring and gesture recognition, not at monitoring the skeleton or the face. It has a sensing frequency of 200 Hz, with an inverted pyramid shaped sensed area, the size of which ranges from 2 mm to 600 mm. Due to its dimensions – 80×30×11 mm – it is a universal sensor. Leap Motion hardware consists of a pair of infrared cameras and three infrared LEDs. Usually, the sensor resides on the desk, between the user and the monitor. The sensor monitors the space above it, specifically, the user's hands. For a detailed description of Leap Motion and the tests performed with it, see [11] and [12]. Leap Motion is used also as a sensor enhancing the possibilities of virtual reality, since, when used with Oculus Rift and HTC Vive headsets, it may be used as a very intuitive controller for virtual reality interaction [13]. Figure 2 shows how Leap Motion sensor works under simple program which we produced under Unreal Engine programming environment.

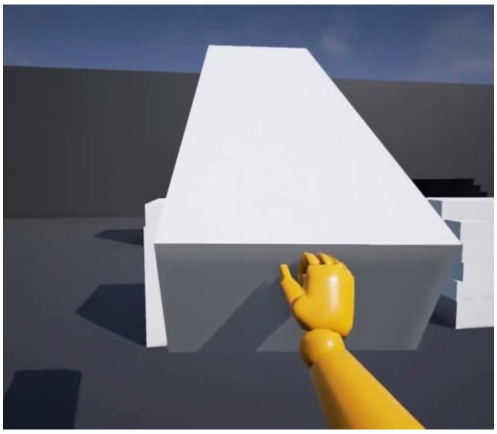

Fig 2:- Leap Motion in Unreal Engine

C. Myo Armband

Myo Armband, a product of Thalmic Labs, was designed to be worn by the user at the widest part of his/her forearm, right below the elbow. It is a sensor bracelet consisting of eight electromyography (EMG) sensors measuring muscle activity, a triple-axis accelerometer, a gyroscope and a magnetometer [14]. It is very accurate and reliable at monitoring hand movements at a frequency of 200 Hz, and, thanks to the EMG sensors, it can distinguish some basic gestures. This sensor uses Bluetooth 4.0 to connect to iOS, Windows, LINUX or Android devices. The authors of [15] managed to experimentally couple Myo Armband and Kinect v2 and saw an increase in the reliability of hand movement and gesture recognition. A particularly interesting feature of the Myo Armband sensor is the ability to classify the sensed gesture information - to speed up their delivery to the computer, it sends only the recognized state information. Nevertheless, one may also opt for acquiring raw data, though this leads to a decrease in the sensing frequency [16].

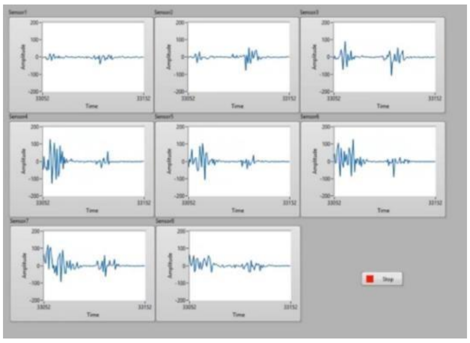

Fig 3:- Front Panel for Myo Armband with the Functions Palette open in LabVIEW

IV. MICROCONTROLLERS AND MICROCOMPUTERS

The current IoT-boom appeared also thanks to the simple development platforms, developed primarily as learning aids for students. These platforms are mostly based on microcomputers or processors employing the ARM architecture. These chips do not offer high processing power. However, they are powerful enough to perform data acquisition, sorting and primary processing. The range of functionality of these, the user-friendly development environment and their cost made learning aids become excellent IoT development platforms.

A. Arduino

Arduino is a microcontroller, which may be utilised in a wide range of situations [17]. The programming language employed by these devices is Wiring, an adapted version of C. Multiple versions of the Arduino prototyping platform exist. The simplest of these is the Arduino Mini, which - to save space -, doesn't even contain a USB port and an external adapter is required for its programming. Nevertheless, the version called Arduino Tre sports a 1 GHz processor. For cost performance reasons, the most widespread version is Arduino Uno. The heart of this device is an Atmel ATMega328p microprocessor. The ATMega328p is an 8-bit processor having 8 analogue input and 14 digital input/output pins. Six of these pins support power management output (PWM). It operates at 16 MHz and has 32 KB of flash memory, 1KB EEPROM and 2KB SRAM [18]. It connects to a computer using a USB-B adapter, which provides also the necessary power. A number of extension modules may be connected to the device, such as Ethernet, Wi-Fi or motor control modules, also known as Shields. The Arduino Wi-Fi shield allows standard 802.11b/g Wi-Fi wireless connection. For secure access, it supports WEP a WPA2 Personal encryption. The

Wi-Fi shield requires a 5 V power supply, provided by the Arduino Uno device. It connects to the Arduino UNO platform using pins with the standard layout, while communication occurs by means of the SPI interface. This extension module includes also a micro SD slot, for memory cards. When connecting the Wi-Fi shield to the Arduino UNO board, pins 11, 12 and 13 are reserved for communication between the board and the connected Wi-Fi module [19]. Pin 4 is used for communicating with the memory card. Digital pin 7 is reserved to create a connection between the Arduino UNO board and the Wi-Fi shield. The various modules use so-called libraries to communicate with the platform. To access the Wi-Fi shield, one has to use the Wi-Fi.h library, offering basic functionality for communication over the network. The Arduino UNO platform may be used to monitor sensor output, process it using simple algorithms and react to the respective situations [20]. Programming Arduino boards involves setting up the basic Setup() function and the Loop() function. Setup() is the part of the program executed only once, defining the libraries, the pins and the initial values of the variables, used during the execution of the program. Loop() is the cycle, which the board repeats over and over. In IoT, the Arduino UNO platform shall be used as a controller in the intelligent network. The Leap Motion, Kinect v2 and Myo Armband sensors are connected to the computer or to the microprocessor, such as the Raspberry Pi 3, which sends the processed data to Arduino. To connect Leap Motion with Arduino, we used Cylon.js, available for download directly from the manufacturer of Leap Motion. The authors of [21] created a highly sensitive robotic arm using the Leap Motion sensor and an Arduino UNO board, while authors of [22] created an ammunition removal robot. To connect Myo Armband with the board, Myo Duino is required - this software is available for download from the manufacturer at Myo Market. The authors of [23] managed to create an army robot using Myo Armband and Arduino. Finally, Kinect was used with a computer and an Arduino UNO board to create a car controlled remotely by the users gestures [24].

B. Raspberry Pi 3

Unlike Arduino UNO, Raspberry Pi 3 is not referred to as a microcontroller, but a microprocessor. Currently, there are some very similar microprocessors available at the market, notable examples being the Asus Tinker board or Latte Panda, using Windows 10 as an operating system. Raspberry Pi 3 has the best cost performance; it is capable of making full use of the aforementioned sensors [25]. To this development board, having a size of a credit card, one may connect a mouse, keyboard, monitor - it is full-blown computer, which may be used for Internet browsing, video playback and the performance of other basic activities. Raspberry Pi 3 is often used as an FTP server and a Web server, respectively [26]. Since it uses the ARM architecture, it does not support Microsoft Windows operating systems. Raspberry Pi 3 has a quad-core 64-bit 1.2 GHz ARM V8 processor. It supports the 802.11N Wi-Fi and the Bluetooth 4.1 low-energy wireless standards. It has 1 GB of operating memory, 4 USB ports to connect peripherals, an HDMI port, an Ethernet port and a 3.5 mm audio output. Instead of a hard disk, the Raspberry Pi 3 platform uses an SD card. A special Linux version, Raspbian - a specially modified version of Debian - is available for the Raspberry Pi 3. For programming Raspberry Pi 3 devices, one may use the Scratch special programming language or Python. Unlike a standard computer, this microprocessor includes GPIO pins, which have to be programmed at the lowest possible level. These serve for the purpose of connecting with the auxiliary sensors. After setting these pins correctly, they may serve as digital inputs, outputs or as low-level UART, I2C and SPI protocols. Raspberry Pi 3 has 40 GPIO pins. After configuring a pin as a digital input pin, it may serve to connect various sensors and read their outputs. Lights or an electric motor could be connected to digital output pins. The microprocessor may then control these devices. Low-level protocols are used to connect and communicate with other modules. A significant disadvantage of Raspberry Pi 3 is the absence of analogue pins, so to connect an analogue input one needs additional ADC circuitry to convert the analogue signals to digital ones. One may connect numerous sensors to Raspberry Pi 3 devices, including accelerometers, compasses, ultrasound sensors or gyroscopes, making Raspberry Pi 3 another motion sensor. Raspberry Pi 3 may be used within the IoT as an alternative to a personal computer; however, its performance does not allow the use of Kinect v2 or Leap Motion. Raspberry Pi 3 is therefore used to gather the information output by the sensors and send them to the computer using the Wi-Fi network. The Myo Armband sensor is connected to Raspberry Pi 3 using a Bluetooth connection and Pyo Connect, a script written in Python, available from the Myo Market.

V. EXPERIMENT OF PRECISION

In our experiment [27] we conducted the research that served to compare the reliability of mentioned sensors. We chose the gestures and movements that are common to these sensors. Pointing is a movement performed to show a particular spot on the screen. Waving is a waving that serves to switch screens and move objects. Hand rotation is a movement that increases the volume, adds or decreases the values determined by the application. Fist is a gesture of clenching fist and the last movement was Fist rotation which represents turning a hand that is snapped in the fist. The Figure 4 shows the percentage evaluation of the obtained results the tracking accuracy of the movements that were made during each movement. We performed 50 experiments for each of the sensors, and we evaluated the practicality of their use for IoT field application.

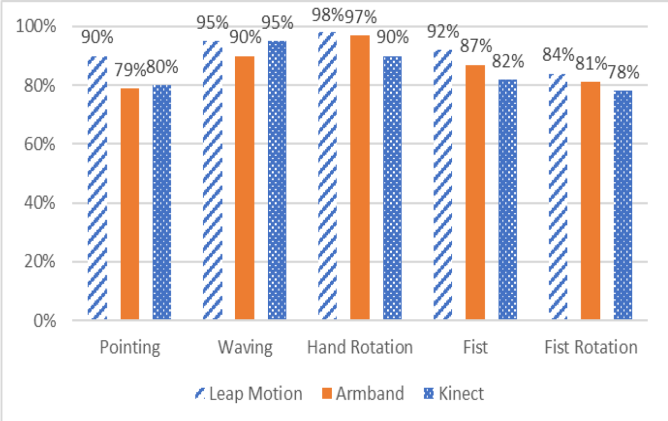

Fig 4:- Summary of sensor efficiency

IoT allows using Arduino and Raspberry, or a similar microcontroller, and we tested their usage. Microsoft stopped produce of Kinect 2018 on 25th October and sold patent to Apple. Apple has already integrated it into the iPhone X. The modified Kinect in this smartphone is placed in the upper ramp and uses it on Face ID function. Face ID emits 30,000 infrared beams and monitors their time of flight to measure depth and recognize the user.

VI. CONCLUSION

Internet of things, as a field, is becoming ever more important - programmers, students and reverse engineers are constantly developing new devices and sensors compatible with it. IoT incorporates motion sensors using infrared light, as well as sensors monitoring the EMG impulses, emitted by the human body. Many papers, dealing with Leap Motion, Kinect v2 and Myo Armband, describing various experiments and robotics solutions implemented using Arduino UNO and Raspberry Pi 3 hardware have already been issued. Even though the computing power of a standard personal computer may not be achieved by these devices, the Raspberry Pi 3 platform has come close to it. In this case, Raspberry Pi 3 may serve as a replacement of a standard personal computer in the communication with the Myo Armband motion sensor and in the subsequent communication with the Arduino UNO platform. The central unit is still the standard personal computer, monitoring and processing the output of the Kinect v2 and Leap Motion sensors, and then, by means of the Raspberry Pi 3 platform, controlling the Arduino microcontroller. The use of Kinect as a sensor is beneficial also due to its microphone array, which it uses to identify the user. Leap Motion may be integrated into the Internet of Things as a sensor, which can reliably recognize the user without the need of touching it, scanning the user's hands. However, the algorithms of such recognition are still under development. The Arduino UNO platform monitors the information sensed by its primitive sensors, sends the information to Raspberry Pi 3 and controls server motors and other active elements. In IoT, Raspberry Pi 3 acts also as a server, to which the user connects remotely, monitoring and controlling the connected devices. This system may be used in an environment with users having locomotor issues, or to provide the security of premises, or to perform education and experiments with motion sensors. An advantage of Raspberry Pi 3 is that it may communicate using Wi-Fi and Bluetooth connections and - if charged by a battery - it may connect to the Internet of things using a wireless connection. Raspberry Pi 3 devices may be used not only as processors of the sensor output, a mediator of communication between the computer and the Arduino UNO platform, but also as a motion sensor, acting as a central unit, monitoring the movements and gestures of the user.

VII. ACKNOWLEDGEMENTS

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