International Journal of
Intelligent Systems and Applications in Engineering
ISSN:2147-6799 www.atscience.org/IJISAE
Advanced Technology and Science
Original Research Paper

Development of a Prototype Using the Internet of Things for Kinetic Gait Analysis

Muhammet Caliskan[1], Abdullah Erdal Tumer*[2], Sumeyra Busra Sengul[3]

Accepted : 21/09/2018 Published: 29/09/2018

Abstract: The proliferation of mobile devices and the gradual development of technology have led to the emergence of the concept of Internet of Things. The IoT has led to an increase in the work done especially on the medical field. The beginning of the reasons for using the IoT in medical studies is to be able to detect and display instantaneous changes that physicians cannot even observe. The aim of this study is to contribute to the recovery of The Gait Analysis from the constraints such as cost, expert necessity and difficulty of measuring the natural walking, and to make Gait Analysis widespread by realizing the more cost-effective. Another contribution of the study is to determine the high pressure points in the foot base and to prevent the loss of tissue in the feet by being produced the appropriate base for the patient. In the study, a prototype placed inside the shoe with the internet of things is developed to monitor the pressure distribution of the foot base. The prototype consists of a thin, flexible insole that collects analog data from the 32 sensors and transmits it wirelessly to mobile or PC via Bluetooth technology. The developed software of the prototype shows the pressure in every sensor on the floor and draws the walking chart. The accuracy and reliability of the prototype are assessed by pre-experimental measurements. The prototype is tested on 14 male and 4 female participants. The prototype is tested on people at 105 kg and below.

Keywords: Internet of Things (IoT), Gait Analysis, Insole, Sensors

1. Introduction

The idea of the Internet of Things (IoT) came into being when 15 academics at Cambridge University used a coffee machine together in 1991. When they went to buy coffee, the academicians who saw that the coffee in the machine was consumed in general, developed a system that would overcome this problem. This system got the picture of the coffee machine one in three (3) minutes and sent it to the academics' computers. Thus, the Internet of things was born as an idea but not as a concept [1].The concept of the Internet of things was first mentioned in 1999 by Kevin Ashton in a presentation for the Procter & Gamble company [1], [2].

IoT has been used in many fields such as Health, Energy, Urbanism, Environmentalism, Agriculture, Animal Husbandry, Shopping, Logistics, Measurement Systems, Industrial Control, Security and Emergency Situations [3].

IoT can be used in different health fields. Diagnosis, treatment, preventive systems, patient tracking systems and remote patient care services are some of these. Two major components of the IoT are: Wireless Body Area Networks (WBAN) and Radio Frequency Identification Systems (RFID) [4].

In the study named as CodeBlue by Malan and his colleagues at Harvard University in 2004, MICA nodes were used and medical applications of wireless area networks (KAA) were investigated. The study was conducted to monitor and record SpO2 and ECG signals of many patients [5].

In their study in 2007, Lee and his colleagues developed a system for monitoring ECG signals and evaluating these signals for home care service in elderly patients. Simultaneously with the developed system, signals were analyzed and an advanced diagnostic facility was provided to the specialist [6].

[1] Industrial Engg., Necmettin Erbakan University –42140, TURKEY
[2] Computer Engineeing, Necmettin Erbakan University –42140,TURKEY
[3] Industrial Engg., Necmettin Erbakan University. –42140, TURKEY
** Corresponding Author Email: tumer@konya.edu.tr*

In their study in 2010, Jara and his colleagues found the adverse side effects of drugs and suggested a platform based internet of things to prevent the side effects of drugs. Patient and drug information was defined in the system. In order to prevent problems that might occur, the patient's allergy information was matched with health information. Patients and doctors were alerted in case of a possible adverse event [7].

In 2013, Zhang and Hu used the Open-Zigbee model to make this model compatible with medical practices. In the study, open source Zigbee model in OPNET program was modified. According to the scenario performed, the physiological data obtained from the patients was transmitted to the system center via the access point. The system analyzed the data coming from the access point and produced results [8].

Yang and his colleagues developed a smart health service system platform based on the internet of things in 2014. In the study, two platforms named IMEDBOX and IMEDPACK were developed. The systems worked with weight sensors installed in medicine boxes. It continuously compared the weight of the box, reported to the main system whether the medication was taken at the relevant time, warned the patient and informed the doctor. RFID and prescription drug information could be uploaded to the system through the database [9]. Figure 1 shows the smart medicine box.

In 2016, Aktaş and his colleagues conducted a study on sending signals from human beings to computer systems using WBAN. It is an important component of the system to transmit the ECG signals obtained in the patient in wireless environment. Simulation of the system is carried out in the OPNET program [4].

In general, in studies, physiological data can be collected while the patient continues his / her daily life, thanks to sensors that can be worn on the patient or placed on the body. In this context, the greatest advantage of wireless systems in terms of patients is that they can lift the limitations of movement and make measurements without leaving the patient's initiative.

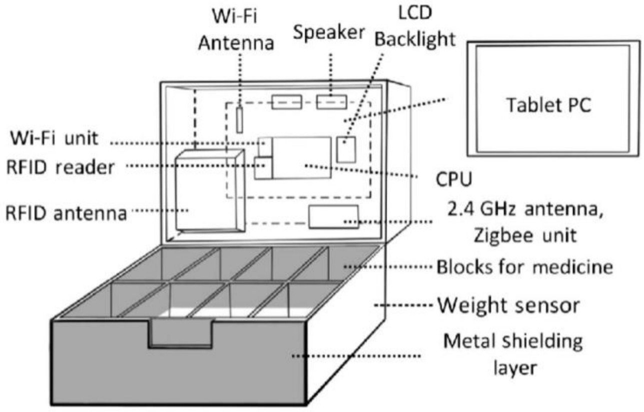

Fig 1. The smart medicine box: Imedbox

Similarly, data collected by using sensors for gait analysis can be interpreted by experts. Gait Analysis consists of a variety of observation-based analysis types such as kinematics, EMG, kinetic analysis. [10]. For a healthy diagnosis these types of analysis should be used together. Kinetic analysis is the study of forces (ground reaction forces, joint moments, joint forces) that cause movement to occur.

The approaches used in kinetic analysis are often the method of analysis of force platforms. The pressure sensors placed on The Walking Track and the pressure on the foot floor detect and transmit these platforms to computer systems [11].

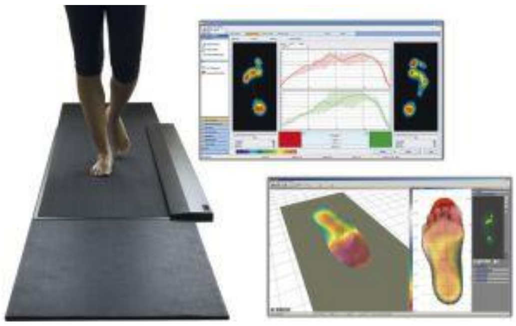

Fig 2. Gait Analysis [Peditürk 2018]

One of the limitations of Gait Analysis is the difficulty of measuring natural walking [12]. In a clinical setting or in a Gait Analysis center, the person being analyzed can change the walking. This can be resolved through the Internet of Things. The measurements of the normal walking in the home or work environment of the person can be sent to specialists by being used wireless technologies.

Bamberg and his colleagues used the shoe in Figure 3 in their study in 2008. The system consists of accelerometer, gyroscope, force sensors, dynamic pressure sensor and height sensors [13].

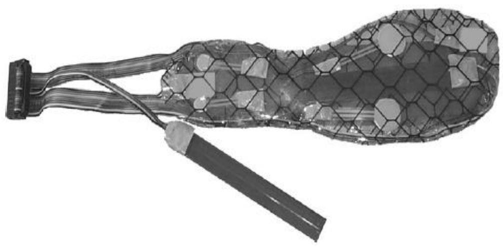

Fig 3. Insole 1

Liu and his colleagues used the shoe in Figure 4 in their work they published in 2010 and 2012. The shoe used consists of 5 pressure sensors [14], [15].

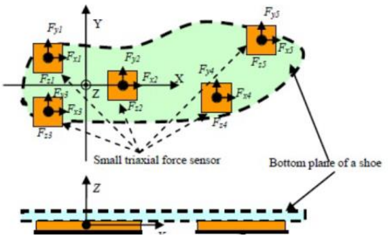

Fig 4. Insole 2

In this study, we has developed a software that shows data and the insole placed in shoes for the use in gait analysis of Internet of Things.The sensors in the developed zone are connected wirelessly via Bluetooth, communicating with mobile devices or PC, and displaying incoming graphs.

2. Development of hardware and software for shoe sole

2.1. Hardware

The prototype's hardware structure consists of 32 force sensors in total, 16 sensors in 2 feet, 2 Arduino Mega 2560, 2 HC-05 Bluetooth Modules, and 2 pcb cards, all of them communicate with each other .

2.1.1. Arduino Mega 2560

The AT mega 2560 is a micro-processor based development card. There are 54 digital input / output pins. 14 of these pins can be used as PWM output. It is the development card that has these features: 16 analog input, 4 UART (serial port), 16 MHz Crystal Oscillator, USB port, adapter input, ICSP output and a reset button [16]. Figure 5 shows Arduino mega 2560.

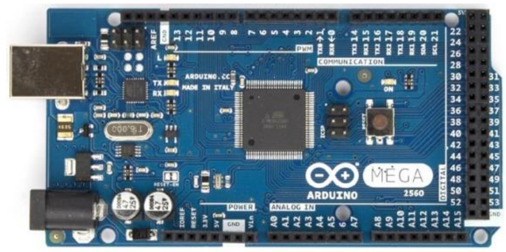

Fig 5. Arduino Mega 2560

2.1.2. PCB

It is the board that allows the sensors to communicate the Arduino with the Bluetooth Module of the Arduino and the sensor to transmit the voltage at the same time. The drawing of the board is made with the fritzing program. It is drawn in accordance with the inputs of Arduino board. Figure 6 shows the PCB in other words the IOT platform.

Fig 6. IOT platform

2.1.3. Force Sensor

Force sensor is force-sensitive resistors. These resistances decrease in resistance values in proportion to the force applied to the active circular area. At this point, force or pressure can be perceived. For touch-controlled electronic devices, it is optimized to detect forces from a few grams to 10 kilograms [17].
In the tests carried out on the product, when no force is applied on the product,1 MΩ and when force like 10 kilograms is applied, 100kΩ resistance values have reached. The values in return for applied force show high consistency. When repetitive constant forces are applied, the test results show that the product produces the same values [18]. Figure 7 shows the force sensor.

Fig 7. Force Sensor

32 sensors in total, 16 sensors in each stand are used in the prototype. These sensors are located on the sole of the foot by examining the pressure points on the sole of the foot and taking the opinions of the orthopedists.

2.1.4. HC-05 Bluetooth Module

It is a card developed for wireless serial communication. In breadboards, the pins required for the convenient use of Arduino and various circuits are transferred to the outside of the card via the circuit board. Supporting Bluetooth 2.0 technology, this card provides communication at a frequency of 2.4 GHz and has a communication distance of approximately 10 meters [19]. Unlike most Bluetooth modules, it also supports Master Mode.

Fig 8. Hc-05 Bluetooth Module

In this study, bluetooth is used as wireless technology for the IoT method. The HC-05 Bluetooth module, shown in Figure 5 as the module is used. Wireless transmission of data, transmission rate, that is, the wireless communication of sensors with software is accomplished through this module. Figure 9 shows the connection of the Bluetooth Module to the Arduino Mega 2560.

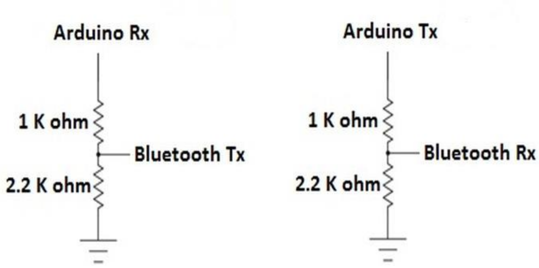

Fig 9. HC-05 Module Connection with Arduino

Figure 10 shows the system graphically. Fig. 11a shows the developed prototype; Fig. 11b shows the prototype placed in the shoe, and Fig. 12 shows the wearable system.

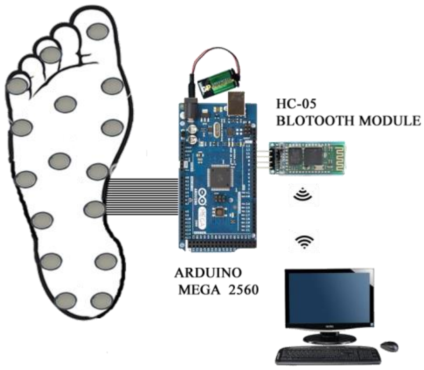

Fig 10. The system graphically

Fig 11a. Prototype **Fig 11b.** The prototype placed

Fig 12. Wearable Kinetic IoT System

2.2. Software System

The system is built using the Visual Studio platform and the C# programming language. The prototype consists of 2 parts. These sections are Upright Posture and Walking. In the upright posture section, it is ensured that the patient is upright on the flat floor to get the patient's data. The system, which receives data from the sensors in 0.2 sec, shows the force distribution on the base of the feet with a graph. If the observed power distributions are not close to each other, the patient will continue to be monitored using other components of the system. The source of the problem here must be investigated. A problem with the joint in the leg applied force or a scar, calluses, heel spurs, etc. on the base of the Foot, could be.In this case, an expert should evaluate the graphics provided by the software.

The second part is the assessment of the data taken during walking. The computer system allows the patient to walk naturally in a walking track with a maximum length of 20 m, provided that they are in the middle of the course. During walking, data is taken from sensors at 200 ms (0.2 sec). By taking the average of incoming data, the average force applied to the soles of the feet at the unit time is calculated. The mean values from two distances constitute the walking graph of the patient.

After the serial port reading process is completed, the software generates some statistical data. These statistical data are the average force of a single sensor during walking and the highest force applied to the sensor.

3. Findings And Discussion

In this study, a system is developed to transmit data from 32 force sensors wirelessly to mobile or PC via Bluetooth technology. The computer system converts this data into a graphical representation. The graphical data represents Kinetic Gait Analysis of the patient during walking. For this system, a flexible base that can be placed inside the shoe has been developed. The system works well even in people with 110 kg. The force distributions on the sole of a standing ankle have been taken as shown in figure 13.

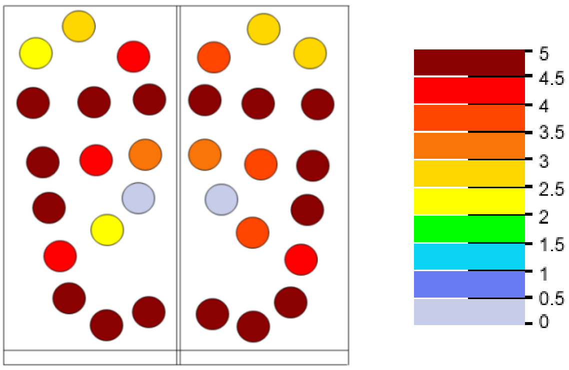

Fig 13. Steep posture data

A walking graph of Figure 14 has been obtained with a data taken from a healthy subject walking 20 meters in a designated course.

Figure 11 shows two series, the left foot and the right foot. The horizontal axis gives the walking speed (The number of steps per minute). The subject has taken about 120 steps per minute.

In the graphic the upper part of the line where the series intersects shows the stepping phase of the walk cycle and the lower part shows the swing phase. In a healthy walk, the peak and bottom values of two feet are expected to be at the same level. Figure 14 shows that peak and bottom levels are at the same level.

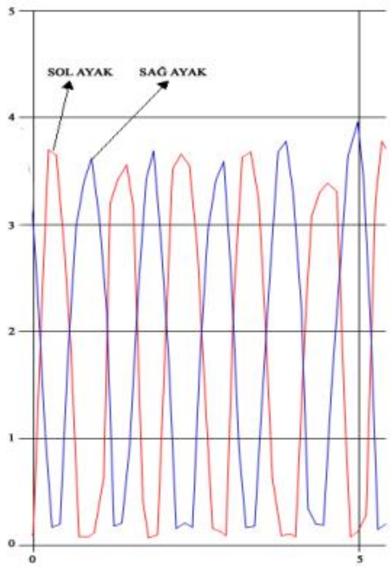

Fig 14. Wolking graph

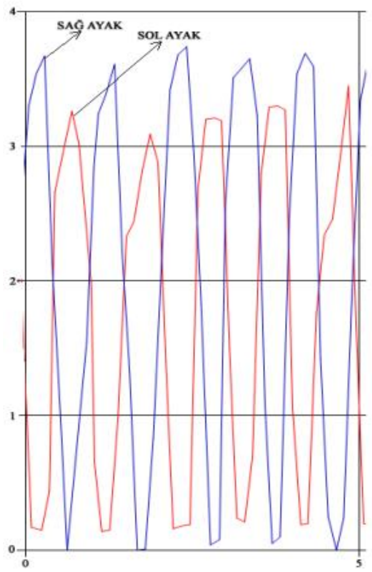

Fig 15. The patient's chart with walking disorder

When Figure 15 is examined, it is observed that the subject has applied more force to his right foot during walking. In addition, when the peak values of the series are examined, it is seen that the peak values of the right foot are higher than the other series. The average force of the feet during walking is:

* Left Foot Average Force: 1.57 kg.

* Right Foot Average Force: 2.07kg.

These forces are measured by the system developed. These values do not produce similar results for all participants. The main criterion is that the values produced on the left foot and the right foot is the same or too closes to each other [20]. These results show that the subject may have a walking disorder. Specialists will start a treatment by examining the graphs. After the treatment, it is possible to decide whether to continue the treatment or to end the treatment by comparing the previous charts with the graphs after the treatment. Another graphic produced by the software is the average force created in a single sensor and the maximum force applied to the sensor. In the Figure 16, here are the results showing that a subject dressed in the system has exerted more force outside the left foot heel than the same area of the right foot.

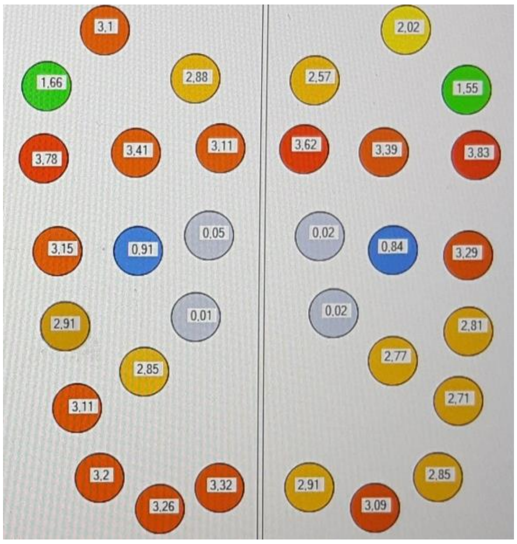

Fig 16. Average force generated by sensors during walking

Figure 17 shows the graph taken from the maximum force applied to the sensors by the subject.

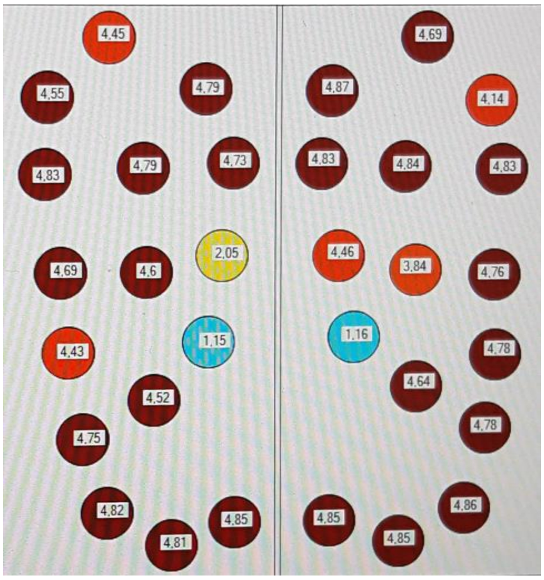

Fig 17. Max. Forces observed from sensors

The range of Bluetooth technology used as wireless communication on the internet of things is 10 m. Instead of Bluetooth in the prototype developed, the coverage can be increased with the technologies like WiFi, GSM, Zigbee. In addition, if mobile devices are used instead of desktop systems, the patient's daily walking measurements can be taken and stored in cloud systems. During the development of the prototype, Arduino mega 2560 as a collection card has been preferred. This is because the stylus is an easy programmable card, many components can be easily added, and ıt has analog input up to (16) the number of sensors used. Since the base equipped with sensors is connected to the electronic circuit board by terminal connector, it can be easily disconnected and installed from the circuit board. A single electronic circuit board and wireless communication unit can be combined with different sizes of bases.

4. Result

Medical problems with the use of the IoTs in the field of health can be observed in natural flow and can be intervened more quickly. It can be measured in the natural flow of walking by the use of the Internet of things in Gait Analysis and a more healthy diagnosis is made by the physician.

One of the biggest limitations of Kinetic Gait Analysis is that it cannot measure normal walking. The system developed in this study consists of a insole equipped with sensors placed in the shoe. The Arduino Mega 2560 card, which has the most analog inputs in the market for the system, the bluetooth technology as a wireless technology and the force sensor as the sensor are used. From the developed system, the walking chart and the forces applied to the sensors are successfully measured and their graphics are drawn. The widespread use of such wearable Gait Analysis Systems, easy and economical availability will allow doctors and patients to follow the treatment processes together and more quickly.

References

[1] N. Kutup, “Nesnelerin Interneti; 4H Her yerden, Herkesle, Her zaman, Her nesne ile bağlantı.” 16. Türkiye’de İnternet Konferansı inet-tr’11, İzmir-Türkiye, pp. 1-5, 2011.

[2] J. López-de-Armentia, D. Casado-Mansilla and D. López-de-Ipina, “Fighting against vampire appliances through eco-aware things. In Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS)” 2012 Sixth International Conference on(pp. 868-873). IEEE, 2012.

[3] L. Görkem and M. Bozuklu, “Nesnelerin İnterneti: Yapılan Çalışmalar ve Ülkemizdeki Mevcut Durum” Gaziosmanpaşa University, institute of science, Gaziosmanpaşa Bilimsel Araştırma Dergisi, Tokat, vol. 13, pp. 47-68, 2016.

[4] F. Aktaş, C. Çeken and Y. E. Erdemli, “Nesnelerin İnterneti Teknolojisinin Biyomedikal Alanındaki Uygulamaları.”Düzce Üniversitesi Bilim ve Teknoloji Dergisi, vol. 4(1), pp. 37-54, 2016.

[5] D. Malan, T. Fulford-Jones and S. Moulton, “Codeblue: An ad hoc sensor network infrastructure for emergency medical care.” In International workshop on wearable and implantable body sensor networks Vol. 5, pp. 12-14, April 2004.

[6] D. S. Lee, S. Bhardwaj, E. Alasaarela and W. Y. Chung, “An ecg analysis on sensor node for reducing traffic overload in u-healthcare with wireless sensor network.” InSensors, 2007 IEEE pp. 256-259.

[7] A. J. Jara, F. J. Belchi, A. F. Alcolea, J. Santa, M. A. Zaaro-Izquierdo and A. F. Gómez-Skarmeta, “A Pharmaceutical Intelligent Information System to detect allergies and Adverse Drugs Reactions based on internet of things.” In Pervasive Computing and Communications Workshops (PERCOM Workshops), 2010 8th IEEE International Conference, Mannheim, Germany, pp. 809-812, IEEE, 2010.

[8] Z. Zhang and X. Hu, December, “ZigBee based wireless sensor networks and their use in medical and health care domain.” In Sensing Technology (ICST), 2013 Seventh International Conference on, pp. 756-761, IEEE,2013.

[9] G. Yang, L. Xie, M. Mäntysalo, X. Zhou, Z. Pang, L. Da Xu and L. R. Zheng, “A health-IoT platform based on the integration of intelligent packaging, unobtrusive bio-sensor and intelligent medicine box.” IEEE transactions on industrial informatics, 10(4), pp. 2180-2191, 2014.

[10] C. Bozer, “Genç erişkinlerde günlük aktivite sırasında yapılan bazı hareketlerin kinetic analizi”, Ph.D THESIS, Trakya University Health Sciences Institute, Edirne, pp. 10-15, 2007.

[11] B. Gülçimen and S. Ülkü, “İnsan Ayağı Biyomekaniğinin İncelenmesi.”Uludağ University Journal of The Faculty of Engineering, Bursa, pp. 13(2), 2008.

[12] G. Yavuzer, "Yürüme Analizi ve Temel Kavramlar." Türk Ortopedi ve Travmatoloji Birliği Derneği Dergisi, İstanbul 13, pp. 304-308, 2014.

[13] S. J. M. Bamberg, A. Y. Benbasat, D. M. Scarborough, D. E. Krebs and J. A. Paradiso, "Gait analysis using a shoe-integrated wireless sensor system." IEEE transactions on information technology in biomedicine, 12(4), pp. 413-423, 2008.

[14] T. Liu, Y. Inoue and K. Shibata, "A wearable ground reaction force sensor system and its application to the measurement of extrinsic gait variability." Sensors, 10(11), pp. 10240-10255, 2010

[15] W. Tao, T. Liu, R. Zheng and H. Feng, "Gait analysis using wearable sensors." Sensors, 12(2), pp. 2255-2283, 2012

[16] A. Alpat, "Arduino Mega 2560 Nedir ?"Arduino Türkiye, 2012 [Online]. Available: http://arduinoturkiye.com/arduino-mega-2560-nedir/Accessed on: Jan. 15, 2018.

[17] 0.6inch Kuvvete Duyarlı Kısa Saplı Dairesel Sensör - Force-SensingResistor - PL-2728, 2018 [Online]. Available: https://www.robotistan.com/06-kuvvete-duyarli-kisa-sapli-dairesel-sensor-force-sensing-resistor Accessed on: Jan. 15, 2018.

[18] 0.6inch KuvveteDuyarlıDaireselSensör, 2018 [Online]. Available: https://www.direnc.net/06-kuvvete-duyarli-dairesel-sensor-pololu Accessed on: Jan. 15, 2018.

[19] HC05 Arduino Bluetooth Modül, 2018 [Online]. Available: https://www.direnc.net/hc05-arduino-bluetooth-modul Accessed on: Jan. 15, 2018.

[20] N. Angunsri, K. Ishikawa, M. Yin, E. Omi, Y. Shibata, T. Saito and Y. Itasaka, "Gait instability caused by vestibular disorders—Analysis by tactile sensor." Auris Nasus Larynx, 38(4), pp. 462-468, 2011.