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IOT-BASED EARTHQUAKE WARNING SYSTEM DEVELOPMENT AND EVALUATION

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Abstract

In this study a low cost earthquake warning system has been developed that will detect non-destructive foreshocks. The developed system is an IOT application where objects communicate with each other. Arduino mega was used as the micro controller in the system. The purpose of developing earthquake warning system is to announce the information about the beginning and end of the earthquake at the instant of earthquake as a tweet in tweeter and to give audible alert for the persons in the environment. IMU and piezo vibration sensors were used to detect the vibrations at the moment of the earthquake. Also, ESP8266 Wi-Fi module was included in the system for the system to connect to the internet. The system evaluates the data from IMU and vibration sensors to detect the earthquake. For IMU sensor, data is evaluated in two axes; namely x and y. ıf the change in x- or y-axis is equal to or greater than 10 or the data from vibration sensor is greater than 694 then the earthquake warning system is triggered. As a result of this triggering the system connects to internet via Wi-Fi module, a tweet is sent to inform that the earthquake has started and audible alert is given locally. ThingSpeak IoT analytics platform is used for the system top send tweet. When the system is triggered, necessary data is sent to the ThingSpeak platform and tweet is sent through this platform. Also, system's sensitivity threshold values can be changed and adjusted. According to the results of real-time operation, it has been determined that the developed system can detect the earthquake successfully and sensitively and provide audible alert and send tweet for warning.

Keywords: Arduino, Earthquake Warning System, Wi-Fi, IoT, Internet of things

IOT TEMELLİ DEPREM UYARI SİSTEMİ GELİŞTİRİLMESİ VE DEĞERLENDİRİLMESİ

Öz

Bu çalışmada, yıkıcı olmayan öncül depremleri algılayacak düşük maliyetli bir deprem uyarı sistemi geliştirilmiştir. Geliştirilen sistem nesnelerin bir biriyle haberleştiği örnek bir IOT uygulamasıdır. Sistem de mikro denetleyici olarak arduino mega kullanılmıştır. Deprem uyarı sisteminin geliştirilme amacı deprem anında depremin başladığına ve bittiğine dair bilgiyi tweet olarak twitter'da duyurmak ve ortamdaki kişiler için sesli uyarı vermektir. Deprem anındaki titreşimleri algılamak için IMU ve piezo titreşim sensörleri kullanılmıştır. Ayrıca sistemin internete bağlanabilmesi için ESP8266 wifi modülü sisteme dahil edilmiştir. Sistem depremi algılayabilmek için IMU ve titreşim sensöründen gelen bilgileri değerlendirmektedir. IMU sensörü için x ve y olmak üzere iki eksendeki bilgiler değerlendirilmektedir. x veya y eksenindeki değişim 10 değerinden büyük ya da eşit ise ya da titreşim sensöründen gelen veri 694 değerinden büyük ise deprem uyarı sistemi tetiklenmektedir. Bu tetiklenme sonucunda Wi-Fi modül vasıtasıyla internete bağlanılarak depremin başladığına dair tweet atılmakta ve lokal olarak sesli uyarı verilmektedir. Sistemin tweet atma işlemini gerçekleştirmesi için ThingSpeak IoT analytics platform kullanılmaktadır. Sistem tetiklendiğinde gerekli bilgiler ThingSpeak platformuna gönderilmekte ve bu platform vasıtasıyla tweet atılması sağlanmaktadır. Ayrıca sistemin hassasiyeti eşik değerleri değiştirilerek ayarlanabilmektedir. Gerçek zamanlı çalışma sonuçlarına göre, geliştirilen sistemin depremi başarılı ve hassas bir şekilde algılayıp sesli olarak ve tweet atarak uyarı verdiği tespit edilmiştir.

Anahtar Kelimeler: Arduino, Deprem Uyarı sistemi, Wi-Fi, IoT, Nesnelerin Interneti

Cite

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1. Introduction

Today, developed high-technology devices are among the indispensable values of modern societies. These technologies that we use for many of our daily needs make our life quite easy. Most of these devices operate independently of each other. In recent years, it is intended for all devices we use in our daily life to communicate with each other and generate a smart communication ecosystem with the Internet of Things (IoT) technology [1].

Furthermore, sensor prices decrease with the advancing and spreading technology, data transmission rates and capacities increase with new generation communication systems and Internet of Things technology begins to enter the daily life more and more [2]. Internet of Things gives the physical things the ability to see each other, hear each other, think and come together 'to talk' in order for them to share information and make a collective decision. IoT is the transformation of basic technologies such as embedded devices, communication protocols, sensor networks, internet protocol and applications from conventional to smart ones [3].

The concept of Internet of Things was first defined by Kevin Ashton in 1999 in a presentation related with the use of Radio Frequency Identification (RFID) technology in the supply chain of P&G firm. [4]. Ashton (2009) emphasised that computers must be strengthened with their own data collection tools; that way they can see, hear and smell the world. He claimed that RFID and sensor technology will facilitate the computer to observe, identify and understand the world without the limitations of the data entered by humans.

Fields of use of the IoT technology is increasing steadily today. Internet of Things is being used in agricultural applications [5], smart home and office applications [2, 6], biomedical applications [3], health applications (3, 7], logistics and vehicle tracking systems [8], energy managements systems [9] and many more fields.

Arduino is a micro controller card commonly used many people in IoT applications. It provides a flexible, easy-to-use and complete hardware and software environment. It can be programmed using a C / C ++ based Processing language. Also, Arduino has an integrated development environment (IDE) for Windows, OS X and Linux systems and there are quite a few number of instructive and comprehensive documents in this environment [10].

The purpose of this study is to develop a low-cost IoT-based earthquake warning systems and evaluate it. In line with this purpose earth quake system was developed and evaluated using Arduino micro controller card, buzzer, wifi module, IMU and piezo vibration sensors.

2. Previous Works

According to the literature search, there are a few works for detecting leading earthquake waves. Böbrek, Kırbaş and Güngör [11] developed a system that detects non-destructive leading earthquake waves using a piezo seismic sensor and micro controller. In this system, the data obtained from the sensor with Labview computer software is read via the USB port and evaluated graphically. Hima et al [12] developed a simple earthquake warning system using an accelerometer and arduino. This device detects the vibrations at small, medium and large scale and displays locally on LCD screen. Novianta et al [13] developed a system using accelerometer and magnetometer sensor that detects abnormal seismic and geo-magnetic ULF waves before the earthquake. Besides these, there are some other works developed with arduino in different areas. Pineño [14] developed the skinner box developed by Skinner, the inventor of acquired conditioning, using iPod Touch, Arduino and servo motor at a lower cost. Dalkılıç and Özcanhan [15] developed a device using arduino uno that can be remotely controlled over Android operating system via Bluetooth. Güngör [16] developed a system using Arduino type micro controller and GSM communication to track unauthorised use of electricity. Lubbe and Kluge [17] developed a device that can be remotely controlled over wireless network and that can transfer images via the camera on it. Radio frequency identification (RFID) method is one of the methods used to identify a person. Ya'acob et al [18] developed a roll call system to check the attendance of students in a laboratory using RFID reader card and arduino mega. Some people are not able to take their cars to maintenance due to their busy working programme. Vaishnavi et al [19] developed a system for the car to pass to the empty lane. In this system, electronic sensors are added to 4 main sections of the vehicle and data from these sensors are evaluated with an algorithm to direct the motors accordingly. Thomas et al [20] developed an auxiliary system for these people. In the developed system data such as oil level, motor temperature and battery voltage are read with sensors and transmitted top arduino card. This data transmitted to arduino card are transformed into a meaningful form and sent via Bluetooth to an application developed on android. Furthermore, the system measures the alcohol level of the driver using the alcohol sensor and warns the driver. Arduino mega card is also used in self-balancing two-wheeled robots. Juang and Lum [21] developed a low-cost self-balancing robot using 2 DC motors, Arduino mega, single-axis gyroscope and 2-axis accelerometer. Yavuz et al [22] similarly developed a balancing two-wheeled robot using arduino uno, feedback data, accelerometer and gyro sensor. They applied three different control algorithms (PI control, PD control, PID control) on the robot they designed, tested these control algorithms and compared their properties such as speed, accuracy and stability. Yalman and Haşıloğlu [23] developed a robot that tracks line to perform medication distribution in hospitals.

3. Method

Development stage of the earthquake warning system is examined in two sections as electronic design and software. In the electronic design, a general diagram was made using arduino mega control card, IMU (Inertial Measurement Unit) sensor, piezo vibration sensor, wifi module and buzzer. Software section includes reading of the data from IMU and vibration sensors, if the threshold level is exceeded connecting to internet over wifi module and sending tweet, and giving audible alert via the buzzer.

3.1. General Design of Earthquake Warning System

First of all, electronic design of the developed earthquake warning system was made. IMU and vibration sensors were connected on the micro controller in order to be able to detect the earthquake. These sensors were tested

and their threshold values were determined. Afterwards connections of the wifi module and buzzer were made. Finally, its programming was done for it to implement the desired functions and it was tested. Simplified general diagram of the designed system is shown in Figure 1.

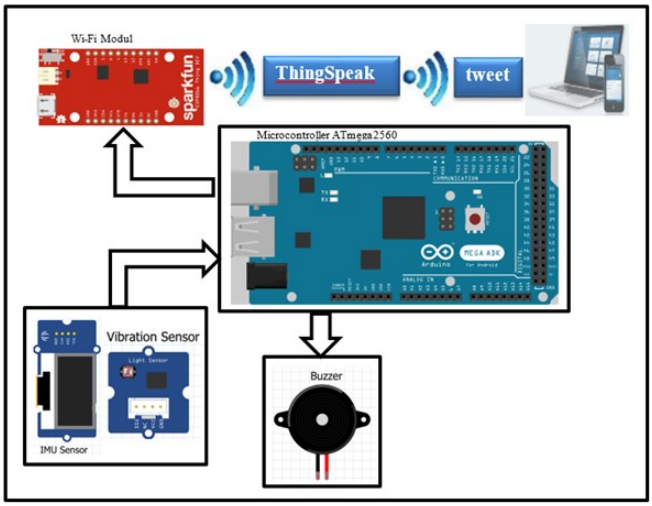


Figure 1. Simplified general diagram of the earthquake warning system.

As seen from Figure 1, when the data from IMU and vibration sensor reaches the threshold value, it is sent to the ThingSpeak IoT analytic platform via the wifi module. A tweet is sent through this platform about the beginning and end of the earthquake. Also, when earthquake begins buzzer is triggered to generate sound.

3.2. Electronic Design

In this section, electronic modules used in the earthquake warning system, their properties and duties are explained. In the design of the earthquake warning system Arduino Mega 2560 control card, Pololu AltIMU-5 acceleration and gyro sensor, Piezo vibration sensor, ESP8266 wifi module and buzzer are used. Electronic design of the system is shown in Figure 2.

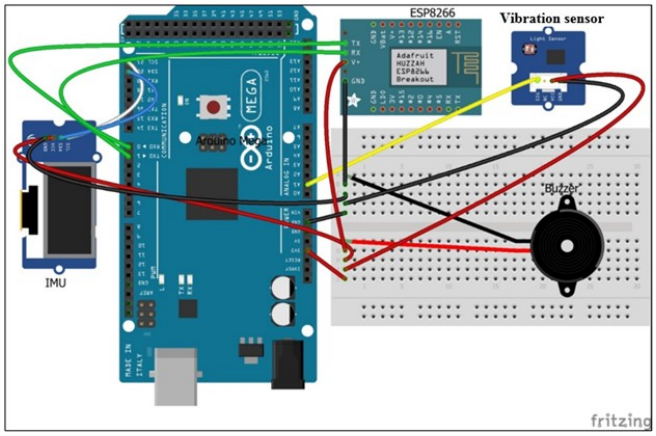


Figure 2. Electronic design of the earthquake warning system.

3.2.1. Arduino Mega Control Card

Arduino micro controller is an open source physical programming platform that implements the basic output applications with peripheral components. Processing/Wiring language is used in this platform [16]. Arduino Mega is a microprocessor card based on ATmega2560 processor. There are 54 digital input/output pins on Arduino mega and 14 of these can be used as PWM output. There are sixteen analogue input pins and 4 hardware serial ports (UART). There are also 16 MHz crystal oscillator, USB connection, one power input, one ICSP cap and reset button on the card. It requires DC 7~12V operating voltage. This card provides everything on it that the micro controller needs. It can be easily connected to a computer with USB cable. Also, it can be started with AC-DC adapter or battery, if desired [18].

3.2.2. Wifi Module

This module is used for uploading data to internet or download data. Wifi module is used to connect to wifi network. Wifi module facilitates data transfer from Arduino to web servers using standard HTTP protocol [24].

ESP 8266 wifi module is used in this study. This module is one of the most capable modules for connecting to internet. ESP8266 can also operate independently without being connected to any micro controller or microprocessor. This module has different versions. The version used in this study is ESP 8266-01 version. This version is the most commonly used and cheap module for small applications where general purpose input/output port (GPIO) is needed less.

Before the module is used, updating process must be performed. When ESP8266 becomes ready, connection is made to the wireless network with the indicated user name and password. When triggering takes place according to the data from IMU and vibration sensors the 'Earthquake began' tweet is sent to ThingSpeak IoT analytical platform over wifi. Tweet is sent over the tweeter account used for entering the ThingTweet at this platform. When the earthquake ends, the 'Earthquake stopped' tweet is sent.

3.2.3. IMU (Inertial Measurement Unit) Sensor

It consists of IMU, accelerometer and gyroscope. Typically each sensor has two or three degrees of freedom (DOF) defined for x, y and z axis. Degree of freedom (DOF) determines the number of independent variables in the system. Acceleration values from accelerometer and angular velocity from gyroscope are kept separately [25]. Accelerometers are used for measuring the position of the device with respect to the earth globe. Maximum value of the accelerometer defines the maximum acceleration it can measure. Capacity selection depends on the application. For measuring events with high acceleration such as shock wave and earthquake, accelerometers having high measurement capacity are used [26].

One of the methods used for measuring angle is the use of an accelerometer. When an accelerometer with 3 axes is held parallel to the ground, it will always give an output at the magnitude of gravitational acceleration (9.80665 m/s2). When there is no motion, no values can be read

from x and y axes. If the accelerometer is tilted in any direction gravitational acceleration will act on these axes and a deviation will be observed in the measurements in these axes [27]. Acceleration sensor has a frequency of 104 Hz and the sensitivity of the frequency significantly high. Considering that earthquake frequency is about 20 Hz, sampling at a rate over five times the earthquake frequency will be sufficient for measurement [11].

Within the scope of this study, the x and y axis data from accelerometer sub sensor of IMU sensor was used. Change in the incoming data was observed to detect if there is any motion or vibration in the objects connected to the IMU.

3.2.4. Vibration sensor card

Vibration sensor can be used for measurements of flexibility, vibration and contact. The module is based on PZT film sensor. When the sensor moves back and forth, a certain voltage is generated by the voltage mixer in it. Its sensitivity can be adjusted with the potentiometer on it. Grove - Piezo Vibration Sensor Card was used in the study. If this card detects vibration when it is powered with 5 volts it gives the value of 1023, when it is powered with 3.5 volts it give the value of 694. That means, threshold value can be used as 1023 or 694. When the vibration sensor is connected to the digital pin, it gives an output in the form of one or zero. Actually, the system can operate correctly and with stability without the vibration sensor. However, a double-sensor system was developed in case one of the sensors fails. It is possible not to add the vibration sensor to the system if it is desired to lower the cost.

3.2.5. Buzzer

Buzzer is a component to generate sound under the control of the micro controller. It is used in the earthquake warning system for issuing audible alert at the moment of earthquake.

3.3. Software developed for earthquake warning system

The software developed for earthquake warning system has been developed using Processing programming language in Arduino IDE environment. Flowchart of the software is shown in Figure 3.

When the system starts to operate the acceleration values at IMU sensor are read in x and y axes. These values are in a wide range such as [-16000, 16000]; for this reason it is difficult to evaluate them. Therefore, mapping operation is made to the range of [-1000,1000]. When the first acceleration values are read, these values are saved as the previous x and y values. Absolute value of the difference between the next acceleration values and oax and oay is taken. If the absolute value is greater than the threshold value, status variable becomes 1 and earthquake warning system is triggered. Buzzer is activated. 'Earthquake began' message is sent to the thingspeak IoT platform over the wifi module. Tweet is sent to the tweeter account determine through the ThingTweet account generated on this platform. In order not to send tweet as long as the earthquake continues, the value of the status variable is saved as the previous status and this way, the change on the status variable is checked. When the status variable becomes 0 that is the difference between the values coming from the acceleration sensors is less than 10, buzzer is deactivated and 'Earthquake stopped' message is sent as tweet.

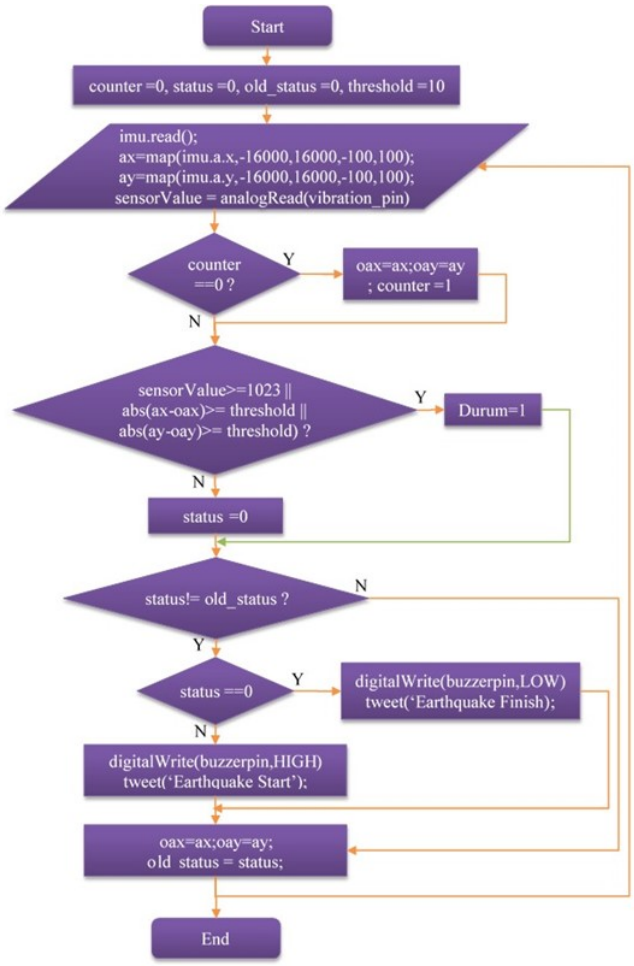


Figure 3. Flowchart of the software developed for earthquake warning system.

Another sensor that can trigger the earthquake warning system is the vibration sensor. This sensor gives the value of 1023 when there is vibration. For this reason, threshold value is taken as 1023 in the software. If the value rad from the vibration sensor is equal to or greater than 1023 system is triggered.

When system is energised wifi module (ESP 8266) gets connected to the wifi network previously loaded into the software. When the earthquake warning system is triggered connection is made to the server to send message to the thingspeak IoT platform with the command line below:

AT+CIPSTART= 'TCP', '184.106.153.149',80

The IP address in this command line belongs to the thingspeak.com web site. ThingSpeak is an IoT platform that allows live data flows to be collected in the cloud, to be visualised, analysed, to send tweet and to read tweets. ThingSpeak facilitates the data sent to ThingSpeak to be

visualised immediately. ThingTweet account has been opened within the scope of this study on this platform.

The following code is used to connect to the indicated wifi network via the wifi module:

AT+CWJAP= 'Baba1', '123456'

AT+CIPSTART= 'TCP', '184.106.153.149', 80

After the connection is established, the following code is used to send messages to Thingspeak platform:

AT+CIPSEND=237

POST /apps/thingtweet/1/statuses/update HTTP/1.1

Host: api.thingspeak.com

Connection: close

Content-Type: application/x-www-form-urlencoded

Content-Length: 77

api_key=L2P6LLNBLSVTJW1B&status=Testintg

Earthquake Warning System: Earthquake Started

Data transfer operation can be followed in serial port of arduino IDE environment as shown in Figure 4.

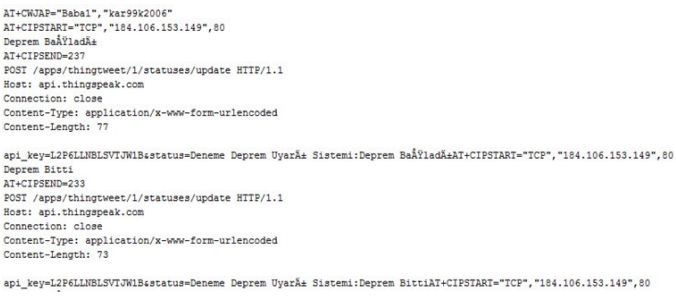


Figure 4. Monitoring of data transmission over Wi-Fi on serial port.

Earthquake warning system was tested and it was observed that it performed the tweet sending operation successfully. The tweet sent as a result of this test is shown in Figure 5.



Figure 5. Sample tweet screen

A video was recorded related with the operation of Earthquake warning system and this video was uploaded to YouTube channel[1].

4. Conclusion and Recommendations

In this study, an earthquake warning system was developed that provides audible alert at the moment of earthquake and also sends a tweet over tweeter as a warning. Audible alert is for alerting the people in the environment of the earthquake to take precaution. Tweet warning is for providing a wider notification about the zone of the earthquake, beginning and end times. In the developed system both IMU and vibration sensor is used for detecting the earthquake. This way, earthquake is detected more precisely and accurately. As a result of the conducted application and tests, it has been observed that the developed earthquake warning system operates correctly. To install the system in a home or office environment both the IMU and the vibration sensor must be mounted on an object that will generate vibration at the moment of earthquake. Threshold value for IMU sensor was determined as 10. This value causes the system to respond very sensitively. For this reason, depending on the object or location where the sensors are to be installed, threshold value can be raised to decrease the sensitivity. According to real time operation results, it has been determined that the developed system detects the earthquake successfully and sensitively and provides warning with sound and by sending tweet.

The developed system can be assembled inside a box and made in the form of a device. Keypad and adjustment button can be added to adjust the threshold value. Also, GSM/GPRS module can be added to the system to send SMS over GSM network at the moment of earthquake.

5. References

[1] Akkuş, S., "Secure Data Communication in Internet of Things Technology–Encrypted Data Communication Application Between Programmable Physical Platforms Using WEP Algorithm", Marmara Technical Sciences Periodical, 3, 100-111, 2016.

[2] Batı, A. C., Coşkun, E., Gözüaçık, Ö., İlhan, G., Şahin, F. A., Uncuoğlu, U., Güngen M. A., Telli, A., "Smart Office Applications Based on Internet of Things for Improved Working Environment and Energy Efficiency", 25. SIU 2017, 1-4, Antalya, 2017.

[3] Aktaş, F., Çeken, C. and Erdemli, Y. E., "IoT-based patient information monitoring system by using RFID technologies," 2016 20th National Biomedical Engineering Meeting (BIYOMUT), Izmir, 1-4, 2016.

[4] Ashton, K., 2009. "That 'Internet of Things' Thing". RFID Journal, http://www.rfidjournal.com/articles/pdf?4986, ziyaret tarihi:20.06.2018.

[5] Çakmak, B., Mercan, E., 2017, "A sample IoT Application in Agricultural Production and Tracking of Old Agricultural Workers", Research Periodical for Aged People's Problems (YSAD),10(1), 29-42.

[6] Oral, O., Çakır, M., 2017, "Concept of Internet of Things and Production of a Sample Prototype", Mehmet Akif Ersoy University, Technical Sciences Institute Periodical, Special Issue 1: 172-177.

[7] Castillejo, P., Martinez, J.-F., Rodriguez-Molina, J., Cuerva, A., 2013, "Integration of wearable devices in a wireless sensor network for an e-health application". IEEE Wireless Commun., 20(4), 38–49.

[1] https://www.youtube.com/watch?v=ZfvPc0mYdm0&t=9s

[8] Ashokkumar, K., Sam, B., Arshadprabhu, R., Britto, "Cloud Based Intelligent Transport System", Procedia Computer Science, 50, 58-63, 2015.
[9] Cho, W.-T., Lai, Y.-X., .Lai, C.-F., Huang, Y.-M., Appliance-Aware Activity Recognition Mechanism for IoT Energy Management System. The Computer Journal, 56(8), 1020-1023, 2013.
[10] Sarik J. and Kymissis I., "Lab kits using the Arduino prototyping platform," in IEEE Frontiers in Education Conference, Washington, 1-5, October 27–30, 2010.
[11] Böbrek, A., Kırbaş, İ., Güngör, T., "Development of Micro controlled Based Earthquake Early Warning System With P-Wave Basis", International Burdur Earthquake & Environment Symposium (IBEES2015), Mehmet Akif Ersoy University, Burdur-Turkey, 7-9 May 2015.
[12] Hima, MS, Subha, J., Kalyani Devi G, Sankaran, K., Naveen S., 2016, "Earthquake Indicator Using Arduino", International Journal of Research in Advent Technology, 4(8), 40-43.
[13] Novianta, M. A., Achmad, M.S.H., Setyaningsih, E., Rakhman, A., "Earthquake Datalogger Using Vibration and Local ULF Geomagnetic Field Measurement", Engineering International Conference 2013 Proceeding, November 21st, Semarang, Indonesia, 2013.
[14] Pineño, O., "ArduiPod Box: A low-cost and open-source Skinner box using an iPod Touch and an Arduino microcontroller", Behavior Research Methods, 46(1), 196-205, 2014.
[15] Dalkılıç, H., Özcanhan, M., H., "Remote Control of an Embedded System Bases Model Mobile Vehicle with Smart Telephone -- AB 2016, January, 2016, Aydın.
[16] Güngör, O., "Tracking of Unauthorized Use of Electricity via GSM", EMO Scientific Periodical, 4(8), 29-33, 2015.
[17] Lubbe, A. J., & Kluge P., "Development and Testing of a Wireless Controlled Car Using the Internet as Communication Medium". South African Journal of Industrial Engineering, 19(1): 137-147, 2008.
[18] Ya'acob, N., Adnan, S. F. S., Yusof, A. L., Azhar, A. E., Naim, N. F., Nur, N. M., Mahmon A., "RFID lab management system using Arduino microcontroller approach associate with webpage", Journal of Scientific Research and Development, 3 (2): 92-97, 2016.
[19] Vaishnavi, D., Sundari, E., Sangeetha, T.V., Shrinidhi, S., Saravanan, P., "Design and Development of Computational Intelligence for Enhanced Adaptive Cruise Control Using Arduino", Applied Mechanics and Materials, 852, 782-787, 2016.
[20] Thomas, A. M., Joseph, J.,Mathew, R., "Mobile Application for Automobile Management System", Journal for Research, 2(2): 66-68, 2016.
[21] Juang, H-S., Lum, K-Y., "Design and Control of a Two-Wheel Self-Balancing Robot using the Arduino Microcontroller Board", 10th IEEE International Conference on Control and Automation (ICCA) Hangzhou, China, June 12-14, 634-639, 2013.
[22] Yavuz, O. İ., Çetin, A., Eyecioğlu, Ö., "Two-Wheeled Self-Balancing Robot", EEB 2016 Electric-Electronic and Computer Symposium, Tokat TURKEY, 11-13 May 2016.
[23] Yalman, S., Haşıloğlu, A., "Development of Nurse Robot Which Makes Simultaneous Medication Distribution in Hospitals", Medical technologies national congress, Bodrum, Muğla, 15-18 October 2015.
[24] Djajadi, A., Wijanarko, M., "Ambient Environmental Quality Monitoring Using IoT Sensor Network", Internetworking Indonesia Journal, 8:1, 41-47, 2016.
[25] Ahmad, N., Ghazilla, R. A. R. Khairi, N. M., Kasi, V., "Reviews on Various Inertial Measurement Unit (IMU) Sensor Applications", International Journal of Signal Processing Systems, 1(2), 2013.
[26] Pınar, D., "Analysis of Accelerometer Signals with Advanced Methods, Master Thesis", Başkent University, Technical Sciences Institute, Ankara, 2017.
[27] Kerimoğlu, K., "Low-Cost Autopilot System Design for a Fixed Wing Unmanned Aerial Vehicle", Master Thesis, Tobb Economy and Technology University, Technical Sciences Institute, Ankara, 2011.