Available online at www.academicpaper.org

Academic @ Paper

ISSN 2146-9067

International Journal of Automotive Engineering and Technologies

Vol. 5, Issue 3, pp. 77 –84, 2016

International Journal of Automotive Engineering and Technologies

http://www.academicpaper.org/index.php/IJAET

**Original Research Article**

# The Prototype Design and Tests of Vibration Controlled Driver Warning System from the Steering Wheel

Habib Gürbüz[1]*, Serhat Buyruk[1]

[1]Süleyman Demirel University, Faculty of Engineering, Depertmant of Mechanical Engineering, Automotive Engineering Undergraduate Program, Isparta, TURKEY.

Received 21 March 2016 Accepted 24 July 2016

## Abstract

In this study, drivers are warned according to detected adverse driving conditions by miniature vibration motors positioned on the steering wheel by obtained information from sensors such as acceleration sensor placed in the center gravity of vehicle, the proximity sensor placed on the rear bumper and rain sensor placed in fender. For this purpose, two different electronic circuit boards are used including firstly center gravity placed in vehicle that has collected signals from sensors and secondly center steering wheel that controlled the miniature vibration motors placed on the steering wheel cover. Wireless communication was established between the two electronic circuit boards. Tests was carried out in real road conditions; it was determined that drivers are warned on steering wheel with vibrations at the different durations (180 Hz frequency) according to the scenario developed for adverse driving conditions using accelerometer sensor, proximity sensor and the rain sensor. It was seen that the developed prototype can be used on available vehicles with small modifications, with a simple montage for a vehicle in the production process.

**Keywords:** Steering wheel, Vibration control, Driver warning system

*Corresponding author:

E-mail:habibgurbuz@sdu.edu.tr

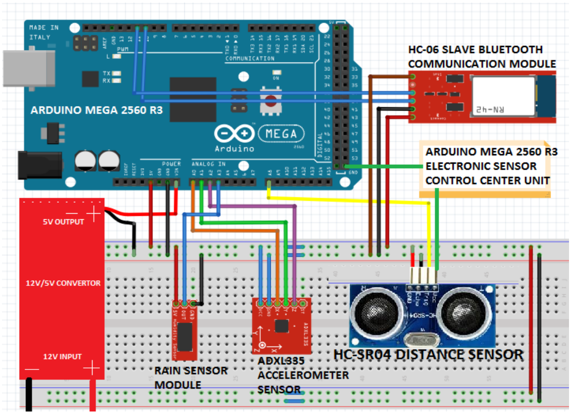
## 1. Introduction

Last years, there has been a great deal of interest in the development of driver assistance systems, in particular collision warnings [1,2].Vehicle collision warning systems using visual, auditory, haptic interfaces has been developed and commercialized[3]. Driver inattention, meaning a lack of concentration, has been identified as one of the leading causes of car accidents, estimated to account for 26 - 56% of all road traffic accidents [4,5]. Thus, sophisticated safety warning systems are now being developed in order to try and promote safe driving [6]. Investigations into the design of optimal warning signals that can alert drivers to potential dangers are essential [7]. One human sense that could potentially be utilized more in a driving environment is the sense of touch. The integration of touch into the traditional focus on vision and audition in automobile design is supported by robust neuropsychological research on the multisensory integration of sensory information [8,9]. The last few years have seen the development of a variety of new technologies, such as sophisticated advanced collision avoidance systems, designed to monitor the traffic environment automatically and to provide additional information to drivers in situations with a safety implication. A great deal of empirical effort has gone into studying how best to alert and warn inattentive drivers to impending danger [10].A driving environment has become more complex with advanced electronic devices and drivers tend to lose their visual attention from the road while receiving information from those devices [11,12].Specially when a driver is focusing on an object with a narrow visual angle, accident risks could increase[13]. Thus, an effective warning can be helpful for attracting attention of distracted drivers when they are unable to detect possible collision situations [14].However, visual warnings have a risk of not being noticed by drivers when they are distracted [15] and the auditory warnings could be masked and not be delivered to the driver because of the ambient noise [16].Therefore, in this paper, drivers are warned with detected adverse driving conditions by miniature vibration motor positioned on the steering wheel using information from sensors such as acceleration sensor placed in the center gravity of vehicle, the proximity sensor placed on the rear bumper and rain sensor placed in fender.

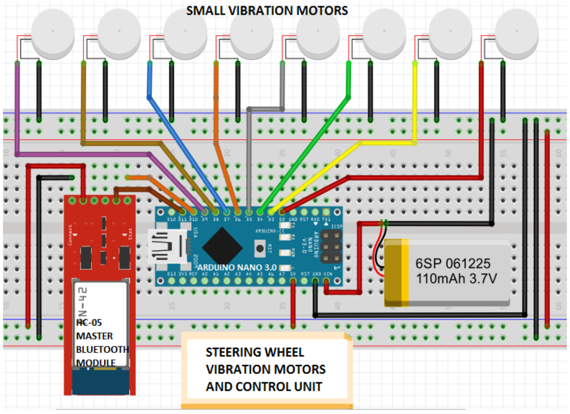
## 2. Materials and Methods

Steering wheel vibration controlled driver warning system consists of two different electronic units which can communicate to wirelessly, these are electronic sensor control unit which was mounted the centre gravity of vehicle and vibration motor control unit which was mounted on steering ring. As it is shown Figure 1, *Arduino Mega 2560 R3* electronic control card was supported by 5V DC input voltage that was converted from 12 V DC car battery via DC/DC converter. *To* determine the vehicle motion in three axis x, y and z ADXL335accelerometer sensor that was mounted centre gravity point of the vehicle, The distance sensor *HC SR04* which was mounted on back side of buffer of vehicle and the rain sensor which was mounted front wheel mudguard were connected to *Arduino Mega 2560 R3* electronic control unit via cables. 8 pieces vibration motors placed with 45 degrees ranges on steering wheel cover that had been mounted on steering ring. The steering wheel cover which had been mounted with small vibration motors previously was fixed on the test vehicle steering ring. The vibration motors were controlled by electronic circuit which was commanded by arduino nano electronic card supported by 3.7 VDC electric source. The communication between steering wheel vibration control system *Arduino Nano 3.0* and the *Arduino Mega 2560 R3*which was mounted centre gravity of car were implemented by one piece *HC-05* master bluetooth communication module and one piece *HC-06 RF* wireless transceiver communication module. *HC-06*

RF wireless transceiver communication module was integrated with arduino mega *2560 R3*electronic card, *HC-05* master bluetooth communication module was integrated with *Arduino Nano3.0* electronic card. Due to master and slave Bluetooth modules automatic wireless communication, both *Arduino Nano 3.0* vibration motors control unit and *Arduino Mega 2560 R3* control unit which was mounted centre gravity of car can communicate each other. Schematic pictures of steering wheel vibration controlled driver warning system was given in Figure 2, and Figure 3, respectively.




**(a)**




**(b)**

Figure 1. **(a)** Electronic circuit diagram of the driver warning system **(b)** wireless connection diagram of the vibration motors on the steering wheel

Singh et. al [19] was reported that connecting two devices via bluetooth requires two phases;

**Inquiry (first stage):**In this process sender broadcasting inquiry packets, which do not contain the identity of sender. And in inquiry Scan receiver devices listen for packets send by sender, and upon detection of any such packets, the device broadcasts an inquiry response packet [19].

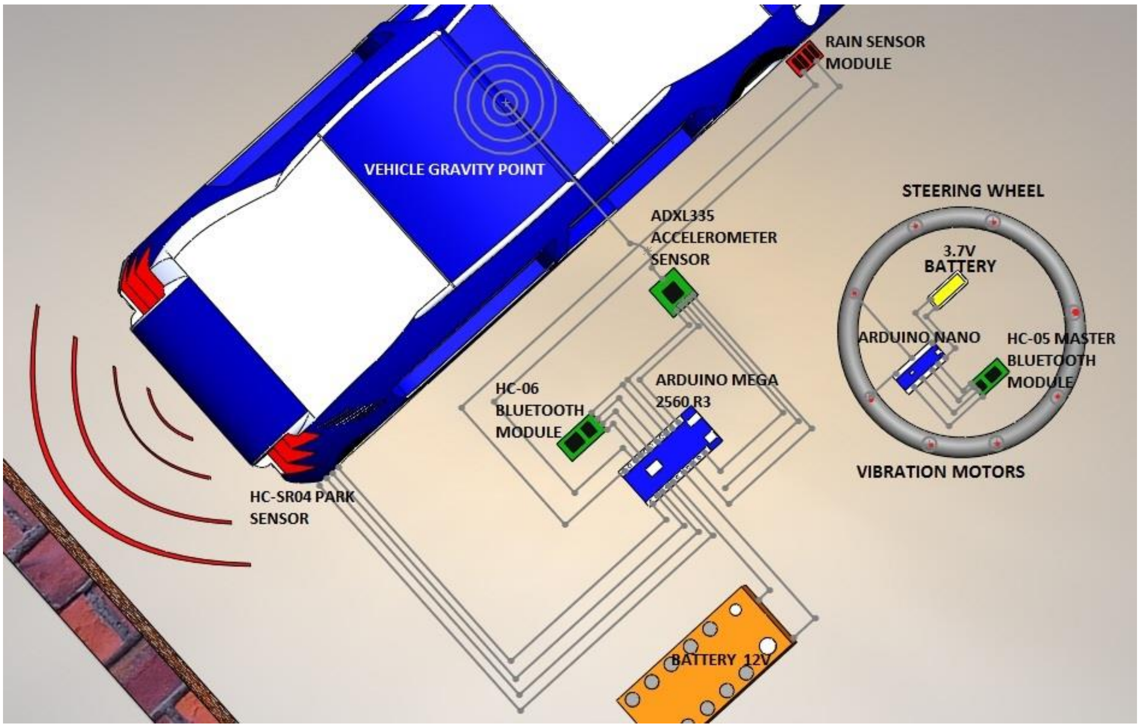



Figure 2. Schematic illustration of vibration controlled driver warning system on the steering wheel


Figure 3. Mounting on the vehicle of improved vibration controlled driver warning system

In this paper, first stage was provided with HC-05 master Bluetooth communication module by determined MAC address communication.

**Page (second stage):** When paging, a sender device tries to form a connection with a device whose identity and clock are known. Page packets are sent, which contain the sender's device address and clock, for synchronization. And in Page Scan that is perform after paging: In this state a receiver device listens for page packets. Receipt is acknowledged and Synchronization between the devices is established [19]. In this paper, second stage was provided with *HC-06 RF* wireless transceiver communication module. Using this kind of communication method on this work, keeps the system away from the cars' electronic components signal frequencies and exposed base stations frequency interferences on cruise states. Flow diagram of vibration controlled driver warning system from the steering wheel is given in Figure 4. Vibration controlled driver warning system that improved in this study was operated literally according to the flow diagram given Figure4 and using prepared programs to the accordance for aims.

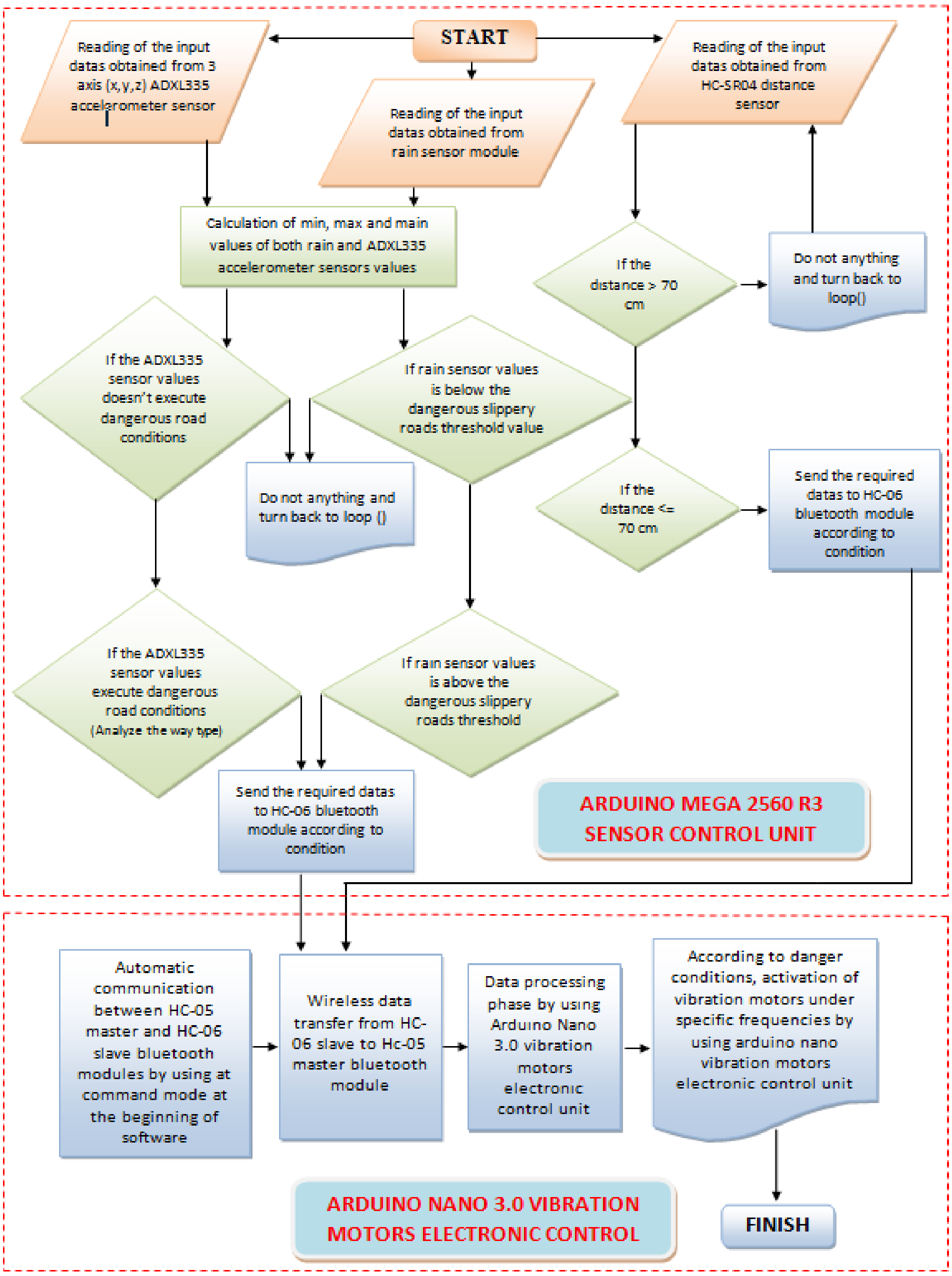
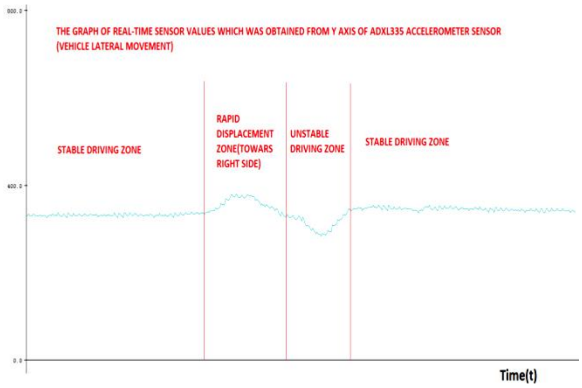



Figure 4. Flow diagram of vibration controlled driver warning system from the steering wheel

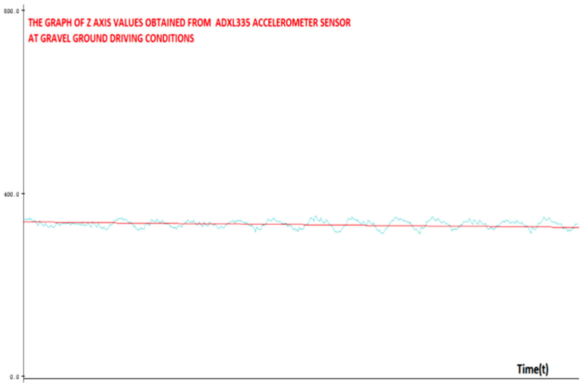
## 3. Discussion and Results

Figure 5 (a) is given the graph of sudden acceleration change in the y axis during change of lane during the straight road driving conditions. The drivers was warned throughout unstable driving stage with 180 Hz vibration frequency (throughout unstable driving zone) of the miniature vibration motor on the steering wheel that is occurred adverse driving conditions with acceleration change in the y axis during change of sudden lane at the straight road driving conditions. In this case, it was informed which impaired direction about the driving stability of the vehicle along the lateral axis (y axis) to driver. Thus, it was informed the driver about needing rotation direction of car's steering wheel for ensure the driving stability.

Figure 5 (b) is given the graph of acceleration change in the z axis during the dangerous gravel road driving conditions. The uneven acceleration change throughout the z axis at the gravel road conditions was ≈transmitted to the driver with 180 Hz vibration frequency (each 3.5 second periods) via miniature vibration motors on the steering wheel. Thus, system informed driver about driving in the appropriate speed of car at the gravel road conditions.




**(a)**



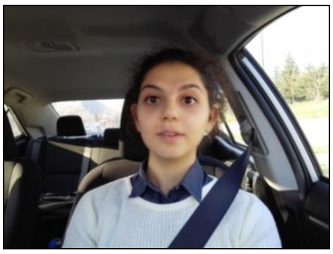

**(b)**

Figure 5. Change of acceleration depending on time collected by the acceleration sensor during driving tests for **(a)** y axis and **(b)** z axis

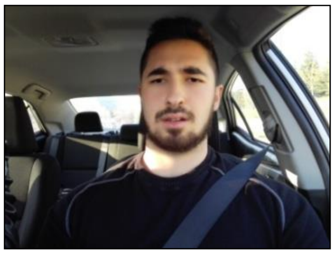
Three different drivers were used in the tests performed under real road conditions. It was observed how drivers feel the vibration warning signal on the steering wheel in adverse driving conditions, it also was recorded by video camera that was attached to rearview mirror. Facial expressions of drivers warned through the steering wheel in adverse driving conditions are given in Figure 6. Three drivers were warned with vibration signals on the steering wheel in adverse driving conditions, and then they have focused on the road surface as shown Figure 6. Driver warning system from the steering wheel that was improved in this study, has warned the drivers positively and the system had useful method about the increasing of attention intensity of drivers. Furthermore, the system has promising features for commercial use.

Relationship between slip ratio and friction coefficient is given in Figure 7 [17].Force is proportional to the slip up to 5 % slip on the vehicle wheel as shown in the figure. The linearity is disrupted increasingly in the range of 5-10 % slip.

**First driver**



**Second driver**



**Third driver**

Figure 6. Facial expressions of drivers during the warning by the steering wheel vibration in adverse driving conditions, and analysis of driver feelings with Microsoft Emotion API

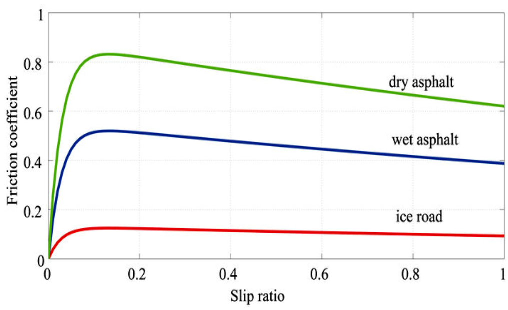



Figure 7. Relationship between slip ratio and friction coefficient[17]

Holding and braking forces were reached its maximum value in the region of 12-20 % slip. Mathematical models generally improves in this region. The friction coefficient decreases in parallel to the increase of the slip [18].

Figure 8 is showing driving tests for detect of the wet asphalt surface that it was performed for warning drivers by using vibration motors on the steering wheel according to obtained information from the rain sensor placed in fender. In these tests, with the adverse driving conditions that occurred reduction of grip force of the wheel on the wet asphalt conditions are transmitted to drivers as the warning with 180 Hz frequency (7 sec.) of the miniature vibration motors on the steering wheel.


Figure 8. Driving tests for detect of the wet asphalt surface

Figure 9 is shown 3D model image (3D model was given as represent to the real conditions) of vehicle approaches (70 cm) to any obstacle that was performed for warning of drivers by using vibration motors on the steering wheel according to given information from the proximity sensor placed on the rear bumper. In this test, the drivers are warned up to collision by 180 Hz vibration frequency of the miniature vibration motor on the steering wheel, when the vehicle approaches to an obstacle.

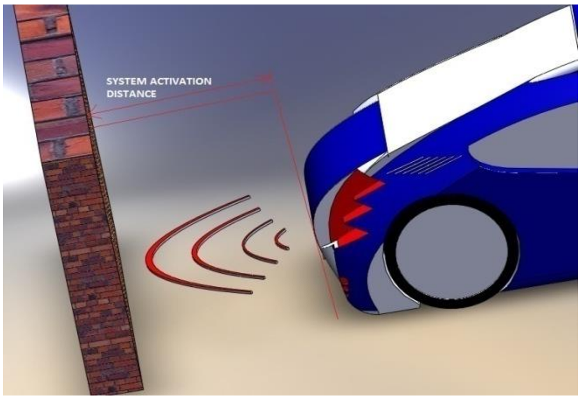



Figure 9. 3D model image when vehicle approaches to any obstacle

## 4. Conclusions

In this study, drivers were warned with detected adverse driving conditions by miniature vibration motor positioned on the steering wheel using information from sensors. In real road conditions obtained results were summarized as follows.

- It was determined that drivers are warned on driving wheel with vibrations at different durations according to the scenario developed on adverse drive using accelerometer sensor, proximity sensor and the rain sensor.

- Vibration controlled driver warning system from the steering wheel that was used in this study has warned the drivers positively and the system is a useful method for the increasing the attention intensity of drivers.

- It was seen that the developed prototype can be used with small modifications on available vehicles and with a simple montage for a vehicle in the production process.

## Acknowledgement

The authors acknowledge the financial support provided for this work by The Scientific and Technological Research Council of Turkey under contract number 1139-B41150148 (TUBITAK 2209–B Industry Oriented Bachelor Senior Project Support Program).

Driving tests was performed with Toyota Corolla brand/model vehicle that was granted by Toyota Motor Manufacturing

Turkey Company to the Süleyman Demirel University, Department of Mechanical Engineering, Automotive Engineering Undergraduate Program. The authors acknowledge for their contribution to the Toyota Motor Manufacturing Turkey company, president of the Automotive Engineering Undergraduate Program.
The authors acknowledge to students of Süleyman Demirel University Automotive Engineering Undergraduate Program [Uğur Uysal (first driver), Ebru Gül (second driver) and Süha Tan KEMENT (third driver) as shown in Fig. 5] for their contribution at the driver tests.

**5. References**

[1] Regan M.A., Lee J.D., Young K.L. "Driver distraction: Theory, effects and mitigation", Boca Raton, FL: CRC Press.,2009.
[2] Spence C., Drive safely with neuro-ergonomics, The Psychologist25, 664 - 667, 2012.
[3] Higuchi M., Raksincharoensak P., Seat vibro tactile warning ınterface for forward vehicle collision avoidance, Proceedings of SICE Annual Conference,1370-1373,Taipei, Taiwan, 18-21 Aug. 2010.
[4] Gibson, J.J., Crooks, L.E., A theoretical field-analysis of automobile driving, Am. J. Psychol., 51, 453-471, 1938.
[5] Wang, J.S., Knipling, R.R., Goodman, M.J., The role of driver inattention in crashes: new statistics from the 1995 crashworthiness data system. In: 40th Annual Proceedings of the Association for the Advancement of Automotive Medicine, 377-392, 1996.
[6] Lee, J.D., Hoffman, J.D., Hayes, E., Collision warning design to mitigate driver distraction, In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 6, 65-72, 2004.
[7]Ho C., Reed N., Spence C., Assessing the effectiveness of intuitive vibro tactile warning signals in preventing front-to-rear-end collisions in a driving simulator, Accident Analysis and Prevention, 38, 988-996, 2006.
[8] Calvert, G.A., Spence, C., Stein, B.E., "The handbook of multisensory processes", MIT Press, Cambridge, MA, 2004.
[9] Spence, C., Driver, J., "Cross modal space and cross modal attention", Oxford University Press, Oxford, UK, 2004.
[10]Spence C., Ho C., Multisensory warning signals for event perception and safe driving, Theoretical Issues in Ergonomics Science, 9(6), 523-554, 2008.
[12] Lin, C., Wu, H., Chien, T., Effects of e-map format and sub-windows on driving performance and glance behavior when using an in-vehicle navigation system, Int. J. of Industrial Ergonomics, 40 (3), 330-336, 2010.
[13] Tang, K.H., Tsai, L.C., Lee, Y.H., A human factors study on a modified stop lamp for motorcycles, Int. J. of Industrial Ergonomics, 36 (6), 533-540, 2006.
[14] Chun J., Han S.H., Park G., Seo J., Lee I., Choi S., Evaluation of vibro tactile feedback for forward collision warning on the steering wheel and seatbelt, Int. J. of Industrial Ergonomics, 42, 443-448, 2012.
[15] Ho, C., Spence, C., Tan, H., Warning signals go multisensory, In: Proceedings of the 11th Annual Conference on Humane Computer Interaction, 22-27, 2005.
[16] Ryu J., Chun J., Park G., Choi S., Han S. H., Vibro tactile feedback for information delivery in the vehicle. IEEE Transactions on Haptics, 3, 138-149, 2010.
[17] Li S., Kawabe T., Slip Suppression of Electric Vehicles Using Sliding Mode Control Method Intelligent Control and Automation, 4 (3), 327-334, 2013.
[18] Bayrakçeken H., Düzgün M., Taşıtlarda fren verimi ve frenleme mesafesi analizi, Politeknik Dergisi, 8(2), 153-160, 2005.
[19] Singh P., Sharma D., Agrawal S., Study of bluetooth wireless technology using java, Indian Journal of Computer Science and Engineering (IJCSE), 2 (3), 295-307, 2011.