A Research On Intelligent Transportation Systems Sensor Technologies

Leyla POLAT[1], Mehmet Önder EFE[2]

[1] *Department of Aviation Management, Faculty of Aviation and Space Sciences, Necmettin Erbakan University, Konya, 42140, Turkey*
[2]*Department of Computer Engineering, Faculty of Engineering, Hacettepe University, Ankara, 06800, Turkey*

Abstract

In the present age, human abilities are transferred to inanimate beings, creating different artificial intelligence, communicating among these objects, making decisions and acting in accordance with these decisions. When it is looked at the technologies and developments made for this purpose, we often come across wireless sensor networks and many sensor technologies. It is almost impossible not to mention the sensors when talking about a smart life.

An inseparable part of smart cities is the transportation and traffic in the cities. For traffic, that is one of the major problems in the world, and for traffic accidents are required that countries should take measures in this regard. Intelligent transportation systems are occurred by using smart technology in this area. These solutions are got mostly thanks to sensors. Sensors play an active role in the determination of the number of vehicles on the roads from the determination of the traffic density to the driving controls of the drivers. The initial question of this study is as follows: 'Which sensors are used in which areas of smart transportation systems and for what purpose?'. In this research, the studies in the literature and the applications where the sensors are used for the purpose of intelligent transportation are examined and conceptual analysis is performed. As a result, the sensors used in this regard are identified and classifications are made among these areas of use in traffic. Moreover, it is aimed to contribute to the academic literature for further applications, which will be developed to address the problems related to the safety of the drivers in traffic and their level of satisfaction in their journeys.

Key Words: Intelligent Transportation Systems, Sensor, Smart City, Wireless Sensor Networks

1. Introduction

Nowadays, the growth of cities makes it impossible for people to go from place to place without using any transportation vehicles. For this reason, the outgrowth of vehicles on the roads occurs in an uncontrolled manner. This increase not only causes great damage to the environment but also increases the waiting times on roads for people and causes various accidents. Studies aiming to eliminate these ailments and raise the welfare level of the society are being carried out. These systems, in which current traffic conditions can be monitored through various algorithms, where immediate intervention can be made when necessary, and which have the necessary equipment for both the driver and the road safety, are generally referred to as Intelligent Transportation Systems. It is seen that these systems will be of great benefit to passengers, drivers, pedestrians and any objects that are on roads [1].

Sensor and communication technologies are the basis of intelligent solutions that will significantly reduce the traffic problem in large settlements [2, 3]. Low cost and highly efficient sensors are based on sensor and sensor nodes. Sensor nodes combine to form a wireless ad hoc network. Thanks to the microcontroller, transceiver, memory, and necessary power supply within the sensor nodes, data from many sensors connected to the node are received, evaluated and stored in memory. Communication in these wireless networks is provided in the form of infrared, radio frequency or optical communication. Sensors that are embedded in these objects are used in order to enable communication of inanimate beings and their own movements by transferring physical life to cyberspaces. A number of data mining and cloud computing algorithms are designed to retrieve

the desired data that are retained at the sensor nodes, to use them as needed by uploading them to a cloud system. In the transportation sector, the same system can be monitored and controlled remotely thanks to both the sensors installed on the roads and the sensors installed in the vehicle. In addition, the communication between the vehicle and the control center and the vehicle can be made through certain protocols in order to ensure safety and regular flow [4]. In this study, it is investigated how smart transportation is possible by sensors and for what purposes where they are used. Sensors are said to lead to major changes in traffic management through wireless networks. Furthermore, it is stated that the efficiency will be kept high by installing sensor-based road systems because of their costs [5]. In this respect, sensor technology is an integral part of intelligent transport and traffic systems.

Sensors are divided into 2 according to the area where they are used in intelligent transportation systems concept. The first of these is the sensors placed on the roads. Thanks to the sensors located on and under the road, problems, and accidents on the roads are prevented and reduced, and life and property safety is ensured. In the second part, there are sensors placed in the vehicles. These sensors enable the driver to focus their attention on their trip and increase their safety and satisfaction by providing the driver with the necessary information about the road. In the course of this study, sensors on the roads and their places of use, and then sensors that are located in vehicles are going to be explained and the purpose and types of these sensors will be specified.

2. Traffic Lane Sensor Technologies

Sensors on highways play a major role in the implementation of intelligent transport systems. In these applications, the main points targeted by these sensors and wireless networks formed by the sensors are as follows [6, 7];

- First of all, to ensure the safety of life, to reduce accident and damage rates,
- Allocating information about physical conditions like weather, road conditions to drivers and controllers,
- Guiding ambulances and firefighters by means of shortcuts for emergencies,
- Optimizing the capacity of the road and thus eliminating traffic congestion.

In order to realize the above-mentioned purposes, sensors and wireless sensor networks on the roads are examined in 2 groups. The first of these is the sensors over the traffic lane. The second group is the sensors that are buried under the traffic lane. These sensors are mentioned in sub-titles in the continuation of our study.

2.1 Sensor Technologies Over the Traffic Lane

These sensors, which can be located on the sides of the road, in the middle or above, do not require any infrastructure or installation. In general, these sensors are effective at image acquisition and at the processing point of these images, thanks to algorithms through the traffic can be reached a number of provisions and can be enabled them to take action. These sensors are positioned in different places according to their intended use. For example, microwave and radar sensors are placed adjacent to or on the traffic lane, while camera sensors are placed on traffic signs, lamps. It is also said that sensors are installed in tall buildings on the side of the traffic lane for a wide area control and radio towers are built for these [8].

As mentioned above, there are many types of on-traffic lane sensors placed in different parts and areas of the road for different purposes. Tewolde's research on this subject and Mimbela et al's project on this subject are examined and sensors over the traffic lane and their functions are brought together in Table 1 below.

Table 1. Sensors Over The Traffic Lane and Their Functionalities

SENSOR NAME	FUNCTIONALITY OF THE SENSOR
Camera	It is used to digitalize the images on the traffic lanes and to interpret them after processing them.
Microwave Radar Sensor	It is used to detect vehicles on the traffic lane and to determine the speed of vehicles and the distance between them.
Infrared Sensor	It is used for tracking traffic flow.
Ultrasonic Sensor	It is used in determining the number of vehicles in traffic, analyzing the current situation and calculating the occupancy rate of the traffic lane.
Passive Acoustic Array Sensor	It is used to determine the noise level by calculating the acoustic energy in traffic, and to determine the occupancy rate of the road.

Source: [8, 9]

2.1 Embedded Sensor Technologies to The Traffic Lane

They are the sensors that are embedded in the traffic lane foundation or attached to the surface of the highway during construction and adjacent to the lanes [8]. They provide more detailed and robust information about vehicles and traffic, but they have many disadvantages. These; the high cost of maintenance and installation of the sensors, these mentioned processes take longer, lead to traffic congestion by disrupting the order of the traffic lane [10].

There are different types of sensors used for vehicle conditions, traffic density measuring. Table 2 shows the types of sensors embedded in the traffic lane and what they are used for.

Table 2. Embedded Sensor Technologies to The Traffic Lane and Their Functionalities

SENSOR NAME	FUNCTIONALITY OF THE SENSOR
Pneumatic Road Tube Sensor	It is used in the classification of traffic density levels by performing the existing traffic analysis.
Inductive Loop Detector - ILD	It is used to determine vehicle crossings, number of vehicles and accordingly road occupancy rate.
Magnetic Sensor	It is used to detect moving or not moving vehicles on the highway. It is also preferred for measuring traffic density.
Piezoelectric Sensor	By learning the number of axles, axle spacing and weight of vehicles on the traffic lane, it is used in vehicle classification, as well as in determining the speed of the vehicle.

Source: [8, 9, 11]

As indicated in the table, magnetic sensors and inductive loop detectors are used to measure the traffic density of the road in which they are located. However, it is reported that the networks formed by magnetic sensors are less costly than the other and provide faster data transmission due to the presence of many sensor nodes and an access point in the network [12].

3. Sensor Technologies Inside of The Vehicle

Due to the development of the automotive sector and accessible to all segments, billions of vehicles in traffic are used. According to Tüik 2018 data, there are approximately 23 million automobiles, vans and motorcycle vehicles registered in Istanbul [13]. Millions of major or minor damaged accidents occur in our cities caused by the driver or vehicle. In order to avoid such mishaps, the vehicles designed in the ITS concept are equipped with high-end technologies to ensure that the driver and other drivers have a safe journey.

Information and communication technologies in vehicles designed so far are not as frequent as they are today. Only the power, speed, and stability of the vehicle on the road are prioritized. However, it is now seen that vehicles do not depend on just drivers' abilities, but on design and artificial intelligence. Many sensors in the vehicle are involved in the construction of the mentioned artificial intelligence and in the interaction of the vehicle with other vehicles and any signs or symbols on the line it is traveling to. In this way, by creating a wireless sensor network, fast and efficient data exchange from sensors is provided [14].

For example, before information and communication technologies reached the current level, drivers were often troubled at their destination and they lost their correct ways frequently. Now, the most suitable, fast ways to reach the destination points are brought to us by the applications in the mobile smart devices and different options are offered along this way. The subject of how this works is as follows; automatic vehicle identification (AVI) system GPS and RFID tags are used as sensors to provide vehicle tracking. The flow of data in the vehicle is provided via the Controller Area Network (CAN) bus. Real-time location information from the vehicle provides online information for the driver and the vehicle via the Internet and all other necessary services [1].

Traffic accidents in the world and in our country occur for many reasons, but sleep is one of the most important factors. It is said that half of the drivers who actively drive in traffic fall asleep at the wheel [15]. It is reported that the age, sex, physiological and mental states are effective in the formation of this condition [16]. Sensors placed in the vehicle, which is within the intelligent transportation systems and which is of great importance, make the necessary determinations about sleep and

give warnings. For example, simple webcams for the day and the IR cameras for the night are placed in the car. They monitor changes in the driver's face and react to certain actions, and by means of image processing algorithms, all these movements are named and sent warning signals to vehicle users [17, 18]. At the same time, the movement of the vehicle on the road, direction and wheel rotation speed, the driver is controlled by monitoring the angles [18]. Another method for the detection of sleep is to monitor the frequency of opening and closing of the eyelids of the user, ISCAN eye-tracking systems are used in addition to the baseball cap in order to obtain a high-resolution image of the eye and to reach certain judgments [19].

In-car sensors with areas of use such as GPS use, sleepy driver detection, as well as other uses are available. According to the literature review, in this study, we have classified these types of usage are under 6 main headings.

- Routing / Location Assistance System
- Lane Change and Tracking System
- Drowsy Driver Warning System
- Blind Spot Monitoring System
- Adaptive Cruise Control System
- Object Detection and Collision Prevention System

In our study, related studies found in the literature are examined and collected in order to determine the sensor types that are considered to be compatible with the above-mentioned fields and they are presented in Table 3.

Table 3. Usage Areas of Sensors Inside Of Vehicle and Related Sensors

USAGE AREAS OF SENSORS OF A VEHICLE	RELATED SENSORS
Routing / Location Assistance System	Gyro Sensor Accelerometer Sensor
Lane Change and Tracking System	Radar Sensor Speed Sensor Camera
Drowsy Driver Warning System	Camera
Blind Spot Monitoring System	Camera Radar Sensor
Adaptive Cruise Control System	Light Detection, Laser Imaging - LIDAR Laser Scanner Radar Sensor
Object Detection and Collision Prevention System	Proximity Sensor Ultrasonic Sensor Electromagnetic Sensor Radar Sensor Laser Sensors

Source: [9, 20, 21, 22]

3. Conclusion & Related Work

Today, it is possible to reach information from anywhere and anytime with the spread of advanced wireless sensor networks to physical environments, by creating ad - hoc networks, by sensing, communicating and exchanging data between sensors. In the introduction part of our study, the working principle of the sensors is mentioned.

If one of the major problems experienced all over the world especially in developed countries is the subject of traffic, the necessary applications are carried out in order to reach a solution with the Intelligent Transportation Systems that have been created by these sensors and gathered under one roof. In our study, transportation problems and solutions are investigated. In fact, it is determined how these intelligent solutions, which are promised and presented, are realized thanks to sensors and what kind of sensors are used for this purpose. It is seen that the optimum efficiency of the traffic lanes is achieved based on the sensors and the information obtained from them. At the same time, traffic lane sensors and other mentioned sensors play an important role for the safety of all drivers who drive vehicles on the road, and for keeping the trip satisfaction levels of drivers high. On a large scale, the areas where sensors and wireless sensor networks are actively used in traffic, transportation and on the vehicle are listed below:

- To monitor and follow the traffic flow (access to occupancy and usage rate about the road),

- Determination of the status of vehicles in traffic (determination of vehicles standing or moving, vehicle speed, evaluation of the distance between vehicles),
- Monitoring traffic flow and ensuring control (providing safety of drivers, pedestrians and other related objects on the road),
- Getting vehicle driving of drivers efficient and safe,
- Realization and elimination of all problems that may occur in traffic in advance,
- Not keeping driving and vehicle control connected to the driver only.

It is thought that our research can be considered as a basis for the studies, projects, and activities planned to be developed on these subjects. Any problems that may disturb safety and peace in traffic or in the vehicle are detected. And once it has been determined that this problem will be solved by sensors, it is desirable to be assisted in where and how such sensors can be used. In the continuation of our study, it is aimed to realize the applications that will ensure the safety of the driver with sensor technologies that are inside of the vehicle we have identified here.

References

[1] Tewolde, G. S. (2012, May). Sensor and network technology for intelligent transportation systems. In 2012 IEEE International Conference on Electro/Information Technology (pp. 1-7). IEEE.

[2] Abdelhamid, S., Hassanein, H. S., & Takahara, G. (2014). Vehicle as a mobile sensor. Procedia Computer Science, 34, 286-295.

[3] Guerrero-Ibáñez, J., Zeadally, S., & Contreras-Castillo, J. (2018). Sensor technologies for intelligent transportation systems. Sensors, 18(4), 1212.

[4] Mukhtar, A., Xia, L., & Tang, T. B. (2015). Vehicle detection techniques for collision avoidance systems: A review. IEEE Transactions on Intelligent Transportation Systems, 16(5), 2318-2338.

[5] L. Latto, «www.connectorsupplier.com,» Connector Supplier + Cable Assembly Supplier, 17 05 2013. [Çevrimiçi]. Available: https://www.connectorsupplier.com/040213-cs-intelligent-transport-systems-sensors/. [Accessed: 01 02 2019].

[6] Guerrero-Ibáñez, J., Zeadally, S., & Contreras-Castillo, J. (2018). Sensor technologies for intelligent transportation systems. Sensors, 18(4), 1212.

[7] An, S. H., Lee, B. H., & Shin, D. R. (2011, July). A survey of intelligent transportation systems. In 2011 Third International Conference on Computational Intelligence, Communication Systems and Networks (pp. 332-337). IEEE.

[8] Dar, K., Bakhouya, M., Gaber, J., Wack, M., & Lorenz, P. (2010). Wireless communication technologies for ITS applications [Topics in Automotive Networking]. IEEE Communications Magazine, 48(5), 156-162.

[9] Skordylis, A., Guitton, A., & Trigoni, N. (2006). Correlation− Based Data Dissemination in Traffic Monitoring Sensor Networks. *2006 ACM Conference on Emerging Network Experiment and Technology*, Lisboa, Portugal, 2006.

[10] Mimbela, L. E. Y., & Klein, L. A. (2000). Summary of vehicle detection and surveillance technologies used in intelligent transportation systems.

[11] Ding, J., Cheung, S. Y., Tan, C. W., & Varaiya, P. (2004). Vehicle detection by sensor network nodes.

[12] Cheung, S. Y., Coleri, S., Dundar, B., Ganesh, S., Tan, C. W., & Varaiya, P. (2005). Traffic measurement and vehicle classification with single magnetic sensor. Transportation Research Record, 1917(1), 173-181.

[13] Kafi, M. A., Challal, Y., Djenouri, D., Doudou, M., Bouabdallah, A., & Badache, N. (2013). A study of wireless sensor networks for urban traffic monitoring: applications and architectures. Procedia computer science, 19, 617-626.

[14] Kumbhar, M. A. (2012). Wireless sensor networks: A solution for smart transportation. Journal of Emerging Trends in Computing and Information Sciences, 3(4).

[15] Heidemann, J., Silva, F., Wang, X., Giuliano, G., & Hu, M. (2005). Sensors for unplanned roadway events-simulation and evaluation. SURE-SE Project Final Report.

[16] Dimitrakopoulos, G., & Demestichas, P. (2010). Intelligent transportation systems. IEEE Vehicular Technology Magazine, 5(1), 77-84.

[17] K. CONGAR, «www.euronews.com.tr,» 05 02 2019. [Çevrimiçi]. Available: https://tr.euronews.com/2019/02/05/tuik-verileri-acikladi-turkiye-de-22-milyon-arac-trafige-kayitli. [Accessed: 01 08 2019].

[18] McCartt, A. T., Ribner, S. A., Pack, A. I., & Hammer, M. C. (1996). The scope and nature of the drowsy driving problem in New York State. Accident Analysis & Prevention, 28(4), 511-517.

[19] Sungur, İ., Akdur, R., & Piyal, B. (2014). Türkiye'deki Trafik Kazalarının Analizi. Ankara Medical Journal, 14(3).

[20] Parmar, S. H., Jajal, M., & Brijbhan, Y. P. (2014). Drowsy Driver Warning System Using Image Processing 1.

[21] Sahayadhas, A., Sundaraj, K., & Murugappan, M. (2012). Detecting driver drowsiness based on sensors: a review. Sensors, 12(12), 16937-16953.

[22] Kozak, K., Pohl, J., Birk, W., Greenberg, J., Artz, B., Blommer, M., ... & Curry, R. (2006, October). Evaluation of lane departure warnings for drowsy drivers. In Proceedings of the human factors and ergonomics society annual meeting (Vol. 50, No. 22, pp. 2400-2404). Sage CA: Los Angeles, CA: Sage Publications.