Intelligent Controller for Monitoring Vehicles at the Roads

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Abstract

Many mobile applications use infrared (IR) and Ultrasonic sensors for distance measurements. In this paper, these two types of sensors have been used in building obstacle detection system and the attributes of each sensor has been tested, the system consists of transmitter and receiver circuit, furthermore, Arduino UNO card has been used for transmitting and receiving signal for each type of sensor based on the Arduino software. The test was performed through distributing these sensors on the road then analyze the reflected signal. Neural network trained and used for monitoring the street and producing the number of cars in each line of street and the total number of cars in the same street.

Keywords: Ultrasonic sensors, Acoustic sensor, IR sensor, monitoring, neural network, Arduino UNO.

1. Introduction

Nowadays, technology is an essential part of human life which is used in various fields; one of these fields is the tracking and monitoring of vehicles at the road which is important for the purpose of security and safety of human life. There are many researches in this area aims to track the position of the vehicles and monitoring their movements. However, it is worthy to say that the process of tracking is not sufficient alone to avoid violations and accidents which occur as results of different factors. Therefore, there are many studies that have been performed in this area to solve this problem; one of these studies is focused on the monitoring of vehicles at the roads instead of tracking vehicles. Our research aims to monitor the vehicles at the roads based on determiming the number of vehicles at the road, in other words, determining the capacity of the road which is useful for decreasing traffic at the roads.

As it's known, there are two types of electronic devices one of them is used to receive the electronic signals such as electrical motors and the other one used to transfer the electronic signal according to physical changes that can be sensed at their circumstances. The last one knows as sensors. Sensors are used to detect the changes that can be occur such as changes that occurred in the electrical charge or calculate the degree of deviations. In this paper, an empirical study details a method that determine the infrared and ultrasonic sensors reflectance properties of a surface and then design a system that monitor the roads using two types of sensors, Acoustic and IR sensors, and based on these proprties.

2. Related Work

In order to build a suitable system that confirms the requirements; many hours may be spent just for sorting, identifying and organizing the necessary sensors that would be appropriate for a certain application such as detecting and tracking of an object. Therefore; in this paper, two types of different sensors, acoustic and IR sensors, are chosen and used in building a system that monitors the road based on several criteria as discussed previously in section (I) and a comparison among the results were occurred.

There are many researches that exploring the difference between the ultrasonic and infrared sensors taking into consideration the advantages and disadvantages of each one of them. In infrared (IR) sensors, the intensity of light which is reflected on a surface is used to calculate the distance from an object [1-3]. Their fast response is useful for enhancing the response of the real-time of a mobile robot [4]; these types of sensors are very sensitive to the IR light and sunlight and this is the main reason of being accurate in the spaces with low light. They have several advantages such as using them over a large area for detecting infrared light, they can operate in real-time, the using of non-visible light for detection and they are cheap sensors. However, some IR sensors depend on the measurement of the phase shift which offers a resolution from 5 cm to 10 m [5] and these types are expensive. Furthermore, they have some limitation such as the weakness to the darker color like black color.

Ultrasonic sensors (acoustic) send high frequency sound waves and receive the reflected echo from the target, they mostly used to measure the distances and considered as a reliable source of detecting obstacles because their independency on the vision. therefore, they are useful in the cases of poor lighting and the colors detection, surface texture detection and transparent objects detection. They have several advantages such as working in critical conditions like dirt and dust, and the availability in cuboid or cylinder forms that are better for freedom design.

However, these sensors have several limitations because of their wide beam-width sensitivity to the radiant surfaces [6] as well as the lack of ability to distinguish the objects within 0.5m [5]. Thus, only reflecting the objects which are mostly normal to the acoustic axis may be detected accurately [7].

3. Proposed System

The proposed controller consists form sensors and intelligent controller. The sensors used to detect the target and detect the vehicles movement in the street, and then send signals to intelligent controller to produce the number of cars in each lane. From the number of vehicles in each lane we can overcome the crowdedness in the street, decreasing the accident in the street and controlling or monitoring other things happening in streets. “Figure 1” shows the block diagram of the system.

Figure 1: The Proposed System

Many sensors were oriented along the street to detect the cars at the street. For simulation results, three sensors for each type are used at the street with three lanes. The sensors send signals to neural network in order to train it for many purposes; each part of the proposed system will be discussed in details. Figure (2) shows the flowchart of the system.

3.1 Sensor Description

In this research, two types of sensors are chosen to measure the ratio of the reflectivity of metals that made into vehicles. These sensors are IR and acoustic sensors.

Infrared (IR) Sensor

The IR sensor emits an electromagnetic signal with speed of 3×108 m/s. It has many features; some of them can be illustrated as follows [8]:

a) The Transmitter and Receiver work within a wave length of 810 nm.

b) From datasheet of IR sensor it is show that Compact high performance distance measuring sensor with built-in Infrared LED and signal processing circuit.

c) Little influence by color and reflective ratio in the reflective object.

d) High accuracy measuring by sequential position detection and mean processing data output.

e) No need to input signal, it can be handled easily.

f) PIN photodiode that detect wide range of light. an optical filter placed in front of the detector which absorbs the unwanted beam and allowed the useful beam in the range of transmitter at wave length 810 nm.

g) A two stage amplifier is used (pre-amplifier) to amplify the weak signal.

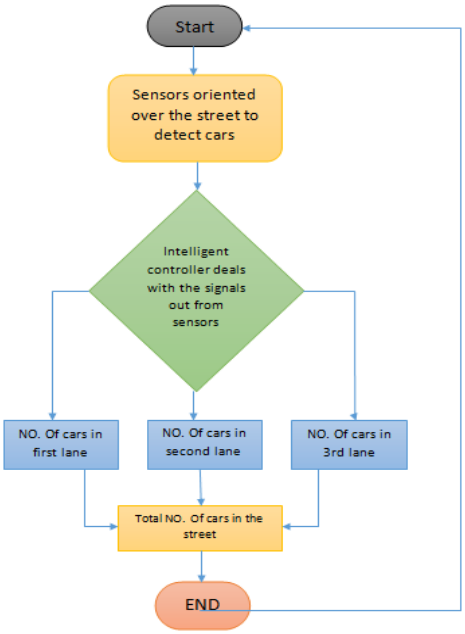

Figure 2: Flowchart of Proposed System

Ultrasounic Sensor (Acoustic)

The human has the ability to hear the sound with frequency between 20HZ ~ 20KHZ, the ultrasonic sensor is the sound wave beyond the human ability of 20KHZ [9]. Ultrasonic transmitter sends the signal in one direction, and started timing when it launched. Ultrasonic travel through the air, and would return As soon as it encountered an obstacles on the way The ultrasonic receiver stops timing when it receives the reflected wave. Ultrasonic spread velocity is 340m / s in the air [9], based on the timer record t, the distance (s) between the obstacle and transmitter can be calculated in equation (1) [9]:

$$s = 340t / 2 \quad (1)$$

Which is called time difference distance measurement principle.

In more details, the air spreading velocity in the principle of distance measurement, the time is calculated starting from the launch until the reflection to an obstacle is countered and then the distance between the transmitter and the obstacle is calculated according to the time and the velocity. Therefore, the principle of ultrasonic distance measurement is similar to the radar. Distance Measurement formula is expressed as in equation (2):

$$L = C X \quad (2)$$

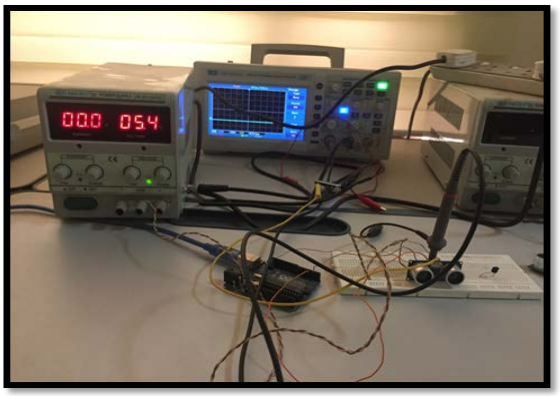

Figure 3: Sensors Connected with Arduino

Where L is the measured distance, and C is the ultrasonic spreading velocity in air, and T represents time (T is half the time value from transmitting to receiving).

There are many features of ultrasonic sensor some of them can be illustrated as follows:

1. Stable performance.
2. Accurate distance measurement.
3. High-density.
4. Small blind.

Some of electrical parameters of ultrasonic sensor can be seen in table (2).

Table 1: Electrical parameter of ir sensor

parameter	Symbol	conditions	MIN	TYP	MAX	Uint
Average supply current	Icc	L=150 cm (NOTE I)	-	30	50	mA
Distance measuring	ΔL	(NOT 1)	100	-	550	cm
Output voltage	V0	L=100cm (NOTE I)	23	25	27	V
Output voltage differential	Δ V01	Output voltage difference between L=100 cm and L=200cm (NOTE I)	0.5	0.7	0.9	V
	Δ V02	Output voltage difference =100 cm and L=200cm/Output voltage difference =200 cm and L=550cm	1.25	1.55	1.85	V

Table 2: Electrical Parameters of Ultrasonic Sensor

Electrical Parameters	HC-SR04 Ultrasonic Module
Operating Voltage	DC-5V
Operating Current	15mA
Operating Frequency	40KHZ
Farthest Range	4m
Nearest Range	2cm
Measuring Angle	15 Degree
Input Trigger Signal	10us TTL pulse
Output Echo Signal	Output TTL level signal, proportional with range
Dimensions	45*20*15mm

3.2 Arduino UNO

There are several techniques that used to deal with the sensors and the control system such as Microprocessor, FPGA, Arduino and others.

Because of the simplicity and low cost, Arduino UNO has been used. In order to read the transmitting and receiving signal, an electrical circuit board which is affiliated to Arduino Company has been used [10]. In more details, it is used to read the signals from the sensors, then processing them to produce the distances to the neural networks to deal with it which results in producing the number of vehicles in each lane at the street and the total number of cars at the street.

3.3 Sensor Conection With the Arduino UNO

Figure (3) shows connected sensors with the Arduino, it consists of two main parts, transmitter and receiver. The transmitter circuit consists of IR and Acoustic sensors, two-stage amplifier, microcontroller, biasing, and oscillator. Furthermore, the receiver circuit divided into two parts according to the type of the sensor; the receiver circuit that used for receiving the infrared signal consists of IR detector, two-stage amplifier, Arduino UNO card. As well as the receiver circuit that used for echo signal detection consists of acoustic pre-amp with pulse width modulation, and Arduino card.

3.4 Biological Neurons

A typical biological neuron is composed of a cell body, a tubular axon, and a multitude of hair-like dendrites, are show in Figure (4).

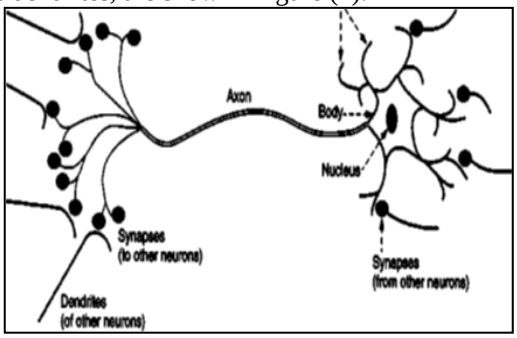

Figure 4: Biological Neurons

The dendrites form a very fine filamentary brush surrounding the body of the neuron. The axon is essentially a long, thin tube that splits into branches terminating in little end bulbs that almost touch the dendrites of other cells. The small gap between an end bulb and a dendrite called a synapse, across which information is propagated [11].

Artificial neural nets model

An artificial neural network consists of a number of very simple and highly interconnected processors, also called neurons, which are analogous to the biological neurons in the brain. The neurons connected by weighted links passing signals from one neuron to another [12]. Weights are the basic means of long-term memory in ANNs. ANN learns through repeated adjustments of these weights. Table (3) illustrates the analogy between biological and artificial neural networks; Figure (5) shows a typical neuron Each neuron receives a number of input signals through its connections; however, it never produces more than a single output signal. [12]. Each neuron computes the weighted sum of the input signal applied some activation function to the net sum then firing an output according to the used activation function, thus the output of the neuron could be depicted as in equation (3)

$$a = f(wi,r * PR + b) \quad (3)$$

Where a is the output of neuron , PR is the Rth input to the neuron, wi,r is the connection weight between neuron i and R input, b bias and f is the activation function of neuron [13].

Table 3: Analogy Between Biological And Artifitial Neural Network

Biological neural networks	Artificial neural networks
Soma	Neuron
Dendrite	Input
Axon	Output
Synapse	Weight

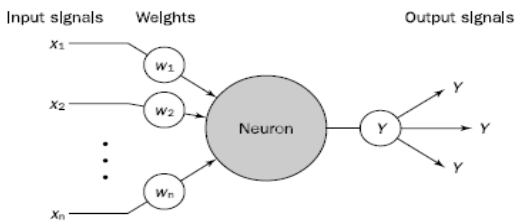

Figure 5: Diagram of a neural

Figure (6) shows a neuron with many inputs and activation function.

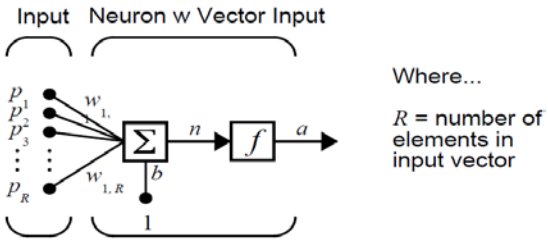

Figure 6: a neuron with many inputs and activation function

There are many algorithms used for training ANN one of them feed forward neural networks (back propagations) algorithms used in training the intelligent controller of the system. The feed forward neural networks consist form input layers, hidden layers and output layers.

4. Hardware and Software Implementation and Results

Firstly, the proposed system created and tested using the simulation. Then, it has been applied in practice using the hardware circuit.

4.1 Simulation results of training the neural networks

The intelligent controller trained by using back propagation with many layers. Each layer and each number on neurons in the layer used in this controller chosen by trial and error. Figure (7) and (8) shows the network used in the controller and the training results for neural network respectively.

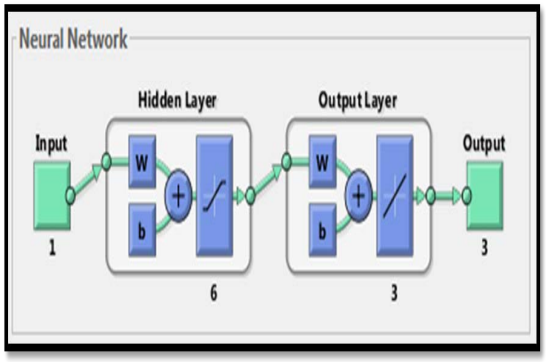

Figure 7: The Network Used in Microcontroller

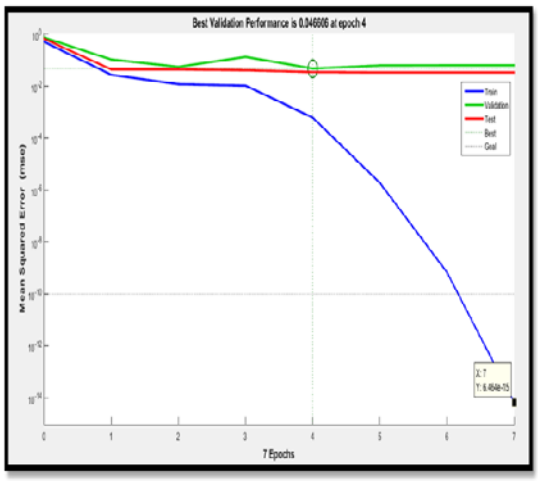

Figure 8: The Training Results For Neural Network

After training the intelligent controller, it is converted to Simulink in order to test the controller with many state and at deferent time. Figure (9) shows the Simulink of controller.

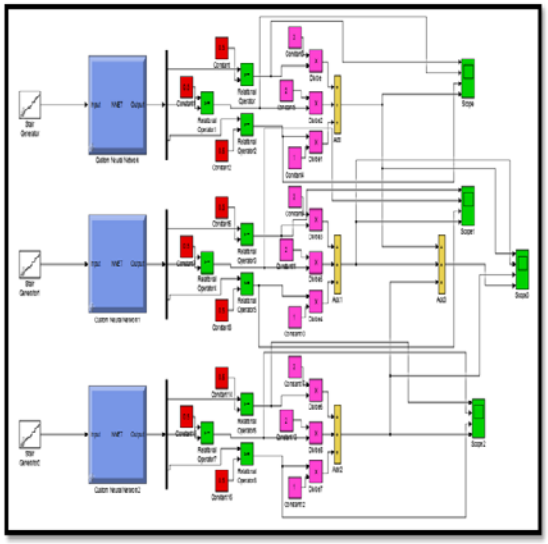

Figure 9: The simulink of controller

in this system, there are three neural networks each one has one input layer, six hidden layers and three output layers such as shown in fig 7. moreover, each network was trained for each detected signal from sensor, the number of sensors used according to the length of the street and distributed with regular distance between each sensor, and for the simulation results. three sensors of each type are distributed at the street. the x-axis of figures taken different values with different time for different states and y-axis present the value as number with the same time. figure (10) shows the distance tracked by sensors and arduino. figure (11) shows the results of neural network for each lane of the street and the number of vehicles at different time. figure (12) shows the results of total number of cars in the street and in each lane of the street.

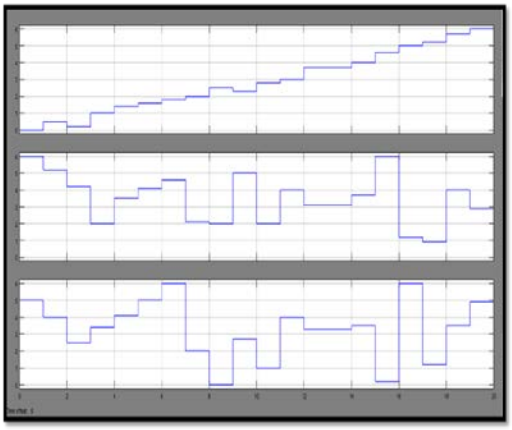

Figure 10: distance tracked by sensors and arduino

4.2 Hardware Results

The experiment takes into consideration three important elements: surface, distance and size. The measurement was taken from 10 cm to 400 cm. In order to monitor the signal relative to the time; an oscilloscope has been used to shows the results. Table (4) shows the comparison between the sensors according to the elements.

IR sensor, the triangulation process is used to determine the distance in which a pulse of light travels and reflects back after a specific time; the reflection light depends on the distance of the reflection obstacles. According to table (3), the results show that the relation between the IR sensor and the obstacle is non-linear as well as the amplitude of the signal is affected by the noise and it is decreased when the distance from the obstacle is increased. Furthermore, the IR sensor could be affected by some sources of lights, such as sunlight and artificial lights. Therefore, the external source must be directly pointed to the sensor [14]. The distance can be calculated from the output voltage using equation (4) [15].

$$Dr = 16.2537\ X^4 - 129.893\ X^3 + 382.268\ X^2 - 512.611\ X + 306.439 \quad (4)$$

Where Dr is the distance measured in cm. Data linearization must be applied because of the non-linearity of the output voltage.

For the ultrasonic sensor (Acoustic), a pulse signal travels from the transmitter to the object, and then an echo signal is back to the sensor. The distance is measured by calculating the reflection time interval between the object and the sensor [16]. Ultrasonic sensor has a principle of pulse width modulation which is useful and accurate to determine the distance. Its amplitude was fixed and not affected by the noise. The duration of the pulse will determine the distance which means that when the distance is increased, the duration of the pulse will increase and vice versa. As mentioned previously, the measurement was

conducted from 10 cm to 400 cm. Figure (13) shows the timing diagram for each distance. It can be calculated using the output voltage as shown in equation (5) [17].

D= (output/voltage)/9.766*2.54 (5)

Where D is distance measured in cm. Therefore, pulse width modulation principle can be used in monitoring the capacity of the roads especially when the traffic is slow and the size of the vehicle is large.

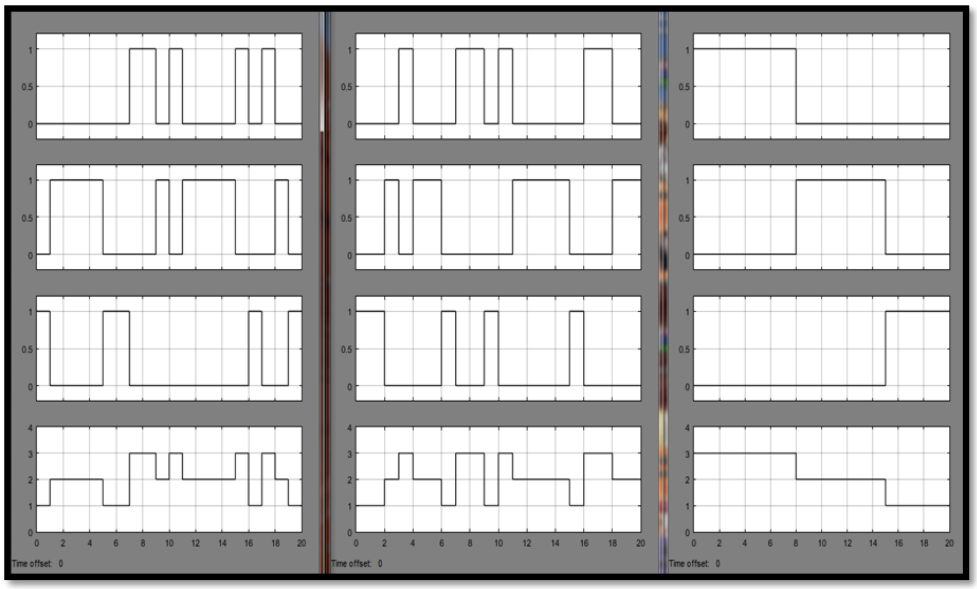

Figure 11: The results of neural network for each lane of the street and the number of vehicles at different time

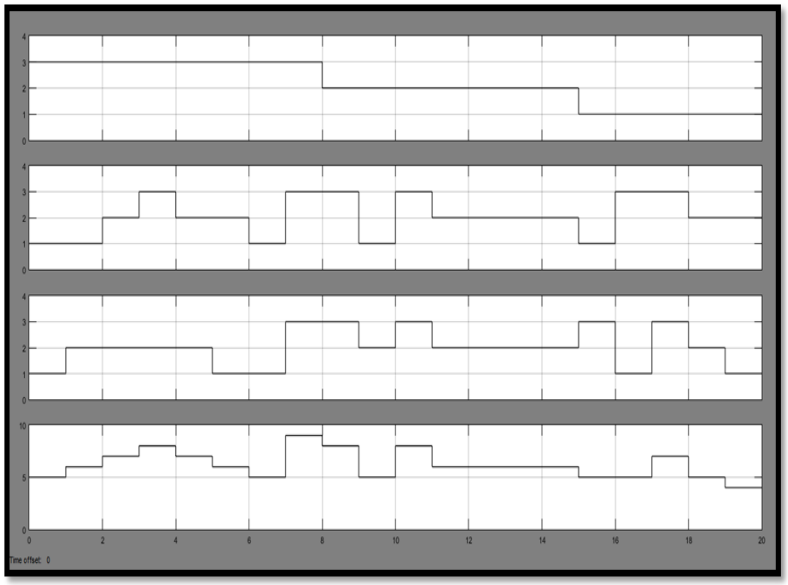

Figure 12: The results of total number of vehicles in each line with different time and random states

Table 4: The Comparison Between The Sensors

Elements	IR Sensor	Acoustic Sensor
Surface	It is independent on the type of the surfaces..	They must be hard and smooth because the test shows that the soft and rough objects present a weak echo which reduces the operating distance and accuracy. Therefore, hard and smooth surfaces reflect greater signal than the other one.
Distance	When the distance is increased then the amplitude of the reflected signal decreased due to the noise.	Distance preferred to be a short as much as possible to return strong echo which means if the distance is increased, then better reflective characteristics is required to return sufficient echo.

Size	It is worked better with small size than the ultrasonic sensor which prefer larger size of the obstacle.	If the size of the object is large, then more surface to reflect the signal. Generally, the closest area to the sensor is recognized as the target.

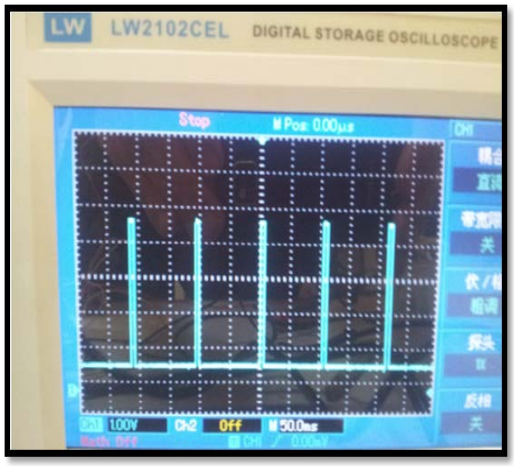

Figure 13-A: When the Distance is 10 cm

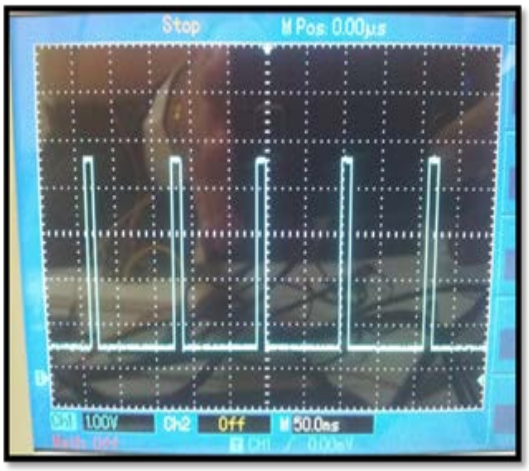

Figure 13-B: When the Distance is 50 cm

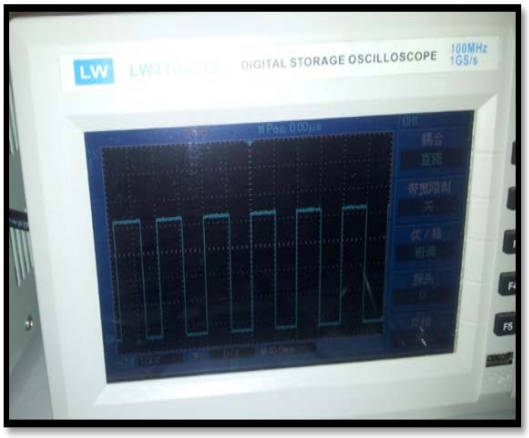

Figure 13-C: When the Distance is 100 cm

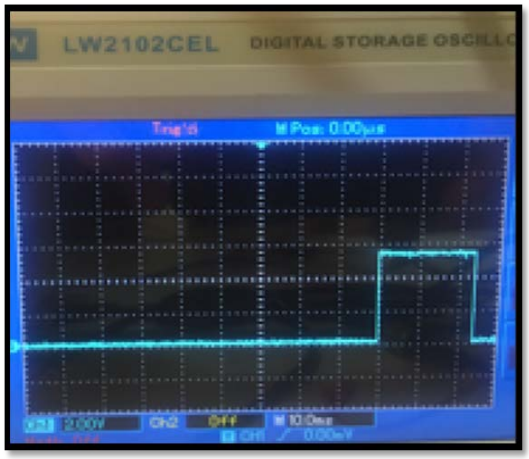

Figure 13-D: When the Distance is 200 cm

5. Conclusion

In this paper, two types of sensors, which are IR and acoustic sensors were tested and compared with each other in practical experiments with the help of Arduino UNO. The results show that the ultrasonic sensor has characteristics and methods to detect the distance different from the characteristics and methods of the infrared sensor; Ultrasonic sensor has a principle of pulse width modulation which is useful and accurate to determine the distance where its amplitude is fixed and not affected by the noise. The duration of the pulse will determine the distance which means that when the distance is increased, the duration of the pulse will increase and vice versa. Both sensors can present reliable results according to their usable range to detect the obstacles. Furthermore, both sensors are independent on the color of the obstacles to determine the distance. The infrared sensor can be used for high speed, which is better than the ultrasonic sensor.

Furthermore, the intelligent controller trained by using back propagation algorithm and used to limit or overcome crowded vehicles in the street and vehicles accident that happened in the daily life by producing total number of vehicles in each street and the number of vehicles in each lane of the same street.

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المتحكم الذكي لمراقبة المركبات في الطرق

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الخلاصة

هنالك العديد من التطبيقات التي تستخدم المتحسسات من نوع (IR) و (Ultrasonic) في قياس المسافات. وفي هذا البحث قد تم استخدام هذه الأنواع من المتحسسات في بناء نظام يهدف الى الكشف عن المركبات الموجودة في الشارع , وقد تم اختبار جميع خصائص المتحسسات المستخدمة في هذا النظام. حيث ان هذه الحساسات تعمل بنظام دائرة الارسال ودائرة الاستلام كما وقد تم استخدام الاردوينو نوع (UNO) للقيام بعمليات الارسال والاستلام. وتم توزيع هذه المتحسسات على طول الطريق و تحليل الإشارات المنعكسة من المتحسسات بعد اصطدامها بالأهداف. وكذلك فأن شبكات الخلايا العصبية الصناعية تم تدريبها لمراقبة الطريق ولكي تعطي عدد الأهداف او المركبات في كل شارع وعدد المركبات في كل خط من نفس الشارع.