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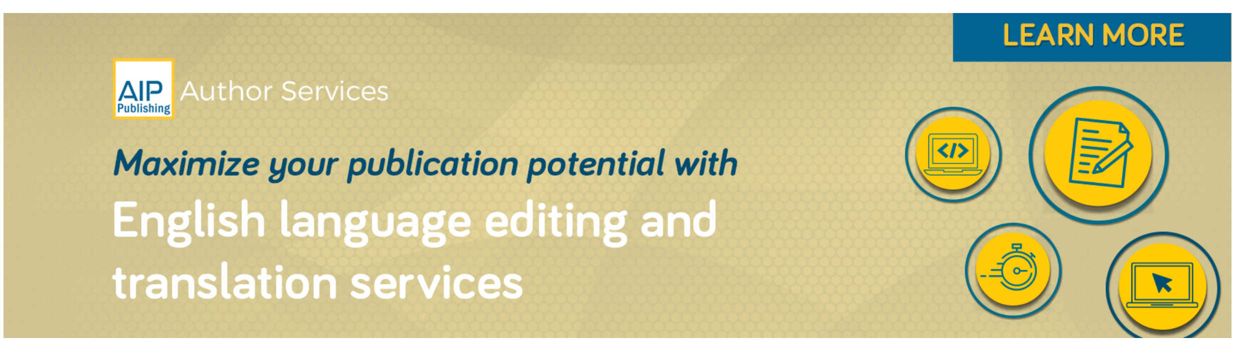

Review and Design of Environmental Smart Detector for Autonomous Vehicle in Urban Traffic

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Abstract. This paper discusses the design and proposed system of autonomous vehicle's detector using ultrasonic array, including the reviews of previous studies. Due to the autonomous, the vehicle has to know its environment of front, rear or side positions. The design places three sensors in front, four sensors in left and right side, two sensor in rear. The front and rear sensors can adapt to vehicle speed in order to increase or decrease range detection to avoid collision. All sensors are controlled by Arduino microcontroller and artificial neural network algorithm. In this research, two types of MaxSonar ultrasonic sensor are used due to its long distance range. This system is being implemented to urban traffic in about 40 km/h maximum speed

Keyword s— Autonomous vehicle, environment detector, ultrasonic array, range finder

INTRODUCTION

An autonomous vehicle is a transportation equipment that moves and runs automatically to the specified path and specified destination. On their way, this vehicle will meet objects that can obstruct the vehicle. It can be other vehicles, pedestrians, or other objects such as portals and traffic officers. For this reason, sensors and systems are needed to detect objects accurately, quickly, precisely and smartly. Furthermore, the existence of objects around the vehicle can be dangerous for the object and for the vehicle itself, which can cause accidents. It is including other vehicle objects in front or behind the vehicle, which are moving or stopping. Each condition requires different settings as the adaptation to detected object [1].

Recently sensor system is limited to providing information or signals if an object is detected. And the implementation of ultrasonic sensor is just for parking assist because of its distance range. But today the improvement of ultrasonic is being long distance reach [2]. So the sensor system proposed here is adopting long range ultrasonic sensor and able to adapt dynamically to the speed of the vehicle, as well as provide braking action if there are the objects in front of the vehicle, with consideration to the distance of the object behind the vehicle, such as another moving vehicle.

To control the vehicle, there are so many methods and algorithms are adopted. The variation mode in design includes hardware and software development to give the action to the system. Most hardware used in recent studies are microprocessor or microcontroller units that have several input and output pins. The softwares recently used to build intelligent system to make smart decision attached to the system are such as PID, fuzzy logic inference, and genetic algorithm [3], [4]. Rare of them using the neural network algorithm. Due to the matter, we chose the artificial neural network algorithm to realize our system..

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PROBLEM DEFINITION

The problem of autonomous vehicle is to detect environmental condition around the vehicle and its ability to prevent accidents automatically. Smart sensors and adaptive system are needed to realize it with selected intelligent algorithm. In this case, system will be applicated in urban traffic condition, so the maximum speed of vehicle is about forty kilometers per hour.

PROPOSED SOLUTION

The system proposed here is to detect environment conditions using multi-point ultrasonic sensor array attached to vehicle body with Arduino microcontroller as controller and artificial neural network as learning algorithm. There are three sensors for detecting front vehicle condition, two sensors on the right side, two sensors on the left side, and two sensors on the rear of vehicle. Each sensor array has different controlling method depends on its function and speed of the vehicle.

PREVIOUS RESEARCH AND SYSTEMS

Autonomous vehicles nowadays are the future of the automotive industry. Human drivers can be replaced by the presence of safe and intelligent automatic vehicles, controlled by hardware and software that have been programmed and embedded in intelligent systems. Autonomous vehicles have an advanced control system in retrieving data from sensors and analyzing the data which can detect and distinguish those objects that are in the environment around the vehicle, whether it is human or pedestrian or other objects that are located around it to avoid unwanted accidents. The autonomous vehicle control method uses the integration of hardware and software that utilizes artificial intelligence system algorithms in the form of machine learning and deep learning, so that the system can learn and study various objects and behavior of vehicles in various conditions [5][6][7].

Another system that is widely used is ADAS (Advanced Driver Assistant System) [8][9][6]. ADAS allows semi-automatic moving cars. It is said to be semi-automatic because the movement of the car is always under monitoring of the driver / operator even though it has run itself according to the algorithm provided. While the system will provide direction and warnings to the driver / operator if there is important information or request approval from the driver.

In their experiment, Kai-Tai Song and the team (2004) designed and implemented an ultrasonic sensor system to avoid lateral accident of vehicle in low speed [9]. The ultrasonic sensor can detect objects with a maximum range of 6 meters at 40 km/h vehicle speed. They choose ultrasonic to use in their system because of its inexpensive cost and suitable for general vehicle implementation, easily obtain range information for the object with simple computation, its robustness to light conditions, and its wide measurement, not only in single point detection. They used Polaroid ultrasonic ranging system as sensors and an AT89C51 microcontroller as main controller in their system.

According to Sivaji (2013) research in “Adaptive Cruise Control (ACC) System for Modeling using Stop and Go Maneuvers”, there are 3 main input to the ACC system. They are speed of vehicle, driver setting time, and the distance measured by the sensors. The system is adapted to control vehicle longitudinally at urban environment with stop-and-go maneuvers. In order for vehicle to effectively follow other vehicle in front of it by keeping the desired distance, the new reference speed is calculated by outer loop controller. Sivaji implemented hybrid PID controller in his intelligent vehicle system[4].

Meanwhile, to develop ACC system and environment recognition for supporting safe driving, Kazuaki Takano and the team used 76-GHz-band millimeter wave radar from Hitachi for application to inter-vehicle distance warning. They designed pre-crash brake systems that automatically tighten seat belts and apply brakes if a collision cannot be avoided. Furthermore, this system has rear blind spot warning, parking assist and stop-and-go maneuvers [10].

Because of ACC system on the market can only run at high speed that makes them useless in urban traffic, Luciano Alonso (2010) also proposed the system that uses the distance between vehicles as measured by ultrasonic sensor to estimate the relative velocity and acceleration, integrated with actuating on acceleration braking system in the vehicle. For measuring the separation distance between vehicles, an ultrasonic system based on a emitter-receiver transducer of 43 kHz has been used. When the distance is greater than 12 meters or there is no vehicles in front, the ultrasonic system reports a fixed distance on this value, preventing in this form an uncontrolled acceleration. It is said that the braking distance at 50 km/h is about 11 meters. The process is repeated each 0.2 seconds. To optimize this system Luciano uses the Genetic Algorithm (GA) [3].

Minal Zunjarrao (2013) deals to ACC system in its operation that achieved through a radar headway sensor, digital signal processor and longitudinal controller. If the lead vehicle slows down, or if another object is detected, the system sends a signal to the engine or braking system to decelerate. Then, when the road is clear, the system will re-accelerate the vehicle back to the set speed [11]. And R. Harris Madhan (2015) used dual ultrasonic distance sensor to realize the fully automated cruise control system with 8-bit PIC 16F877A microcontroller as the brain of the system. In this prototype ultrasonic sensor HC-SR04 is used [12].

In the same year, Rajanikantha (2015) also proposed the advanced adaptive cruise control for an automobile using 16-bit R5F102AA microcontroller combined with 8-bit P89V51RD2 and MG 87FE52AE microcontroller [13].

Priya Hosur, et al. (2016) conducted an ultrasonic sensor test using the 1-sensor and 3-sensor methods by observing the distance and the transmitting angle of each sensor. The system used in this test implements the LV-MaxSonar EZ Series ultrasonic sensor, with the SAMD20J18 microcontroller and Atmel Studio 7 IDE programming utilizing a standalone C language for compiling programs to the microcontroller. Characteristics of LV-MaxSonar EZ Series sensors require a power supply of 2.5 - 5.5 volts with a range of 0 to 254 inches (6.45 meters). The sensor placement is positioned horizontally 90 degrees towards the vertical axis. For 3-sensor testing, 3 configurations are carried out: parallel, the difference is 90 degrees and the difference is 45 degrees. The single sensor test results (1-sensor) show a maximum distance of 79.50 inches on a 90 degree angle and a minimum distance of 16.01 inches at an angle of 55 degrees. While the 3-sensor test (difference of 45 degrees) results in a maximum range of 30 degrees, 90 degrees and 150 degrees with an average distance of 81 inches. The minimum range of 33 inches is at 0.180 and 180.01 degrees [14].

Unfortunately, Hosur's testing is done partially, not using all 12 ultrasonic sensor units, and no real implementation to the vehicles, in stop or moving condition. Testing of 3 sensors is implemented on a 45 degrees difference only, while for 90 degrees difference is not done. The position of the sensor at the test remains at 90 degrees, vertical testing angle variations are not done. There is no explanation of the mechanism to vary range of sensors using a variety of voltage sources. The system does not implement an artificial intelligence system.

While Jiaying Yu, et al. (2016) chose ultrasonic sensors beside of other types of sensors because the ultrasonic has the potential to implement a wider range of low cost, wide detection angles, small/narrow blind zones, and robust to various lighting conditions. By strengthening the signal using a signal processing circuit, the ultrasonic signal detection range can be increased. The thing proposed in this study is an increasing the ultrasonic sensor performance model related to additional factors such as sharpness of objects and object surface material, where the model can be implemented in the traffic lane environment. The experimental design was adopted to analyze the characteristics of the ultrasonic sensor. Experiments use 4 main components, namely target objects, ultrasonic sensors, control circuits and a PC. The control circuit uses an Arduino microcontroller that can instruct the ultrasonic sensor module to emit pulses serially and can capture back pulses when they hit objects. There are 4 characteristics of the object under consideration: the smoothness of the object, the surface material, the distance relative to the sensor and the orientation relative to the sensor's middle path. The distance is about 0.5 to 5 meters. The orientation angle is -60 degrees to 60 degrees, with 10-degrees intervals. Objects use 3 shafts: thin, thick, flat. Three types of surface material is metal, PVC plastic, and fabric. The configuration of the sensor array in this study uses 8 sensors on each side of the vehicle with a distance of 50 cm each sensor. There are 2 types of sensors, serial and mutual readings. This research uses the mutual reading because it requires more information for tracking accuracy in a dynamic environment [15].

Tests and sensor measurements are applied in vehicle speed of around 5 km/h to 10 km/h, for fear of the influence of wind. The tracking algorithm uses the Extended Kalman Filter (EKF). A centralized EKF tracking performance evaluation is performed using the Advanced Triangle Method (ATM) as a comparison. Implementation and testing of tracking with EKF has not been presented. Setting the placement angle of the ultrasonic sensor module is not delivered. Detection is only for the side of the vehicle, not for front and rear.

In his research entitled "Ultrasonic Sensors in Urban Traffic Driving-Aid Systems", Luciano Alonso (2011) applied ultrasonic sensors in vehicle safety systems located on urban road traffic, using the Adaptive Cruise Control (ACC) method, adaptive roaming control and Genetic Algorithm (GA). In his research, he has implemented a fully automated prototype vehicle and tested on real road conditions, and produces excellent ultrasonic sensor performance. Ultrasonic testing uses a maximum speed of 50 km/h according to normal urban speed, and a maximum detection distance of 10 m, according to the ability of an ultrasonic sensor. Some of the subsystems observed is including the front of the vehicle in the form of speed and distance, an ultrasonic system with a detection distance of 10 times per 1-10 meters, a controller that controls speed and braking, the rear, a safe distance in braking. The ultrasonic sensor used is Hexamite HXN43TR in the form of a transmitter-receiver unit with a working frequency of 43 kHz (tolerance of 5 kHz) and bandwidth of 4 kHz, -3dB. The signal from the sensor is filtered using a Band pass filter, with an upper limit of 44 kHz and a lower limit of 42 kHz. Genetic Algorithm is determined randomly (try and error) and the best value is k1=1.7, k2=12.14, k3=15.75, and the number of J is 0.63 [16].

METHODOLOGY

The research is designed to be as shown at Fig. 1 that planned to use ultrasonic sensors arranged in an array to detect objects around the vehicle. It is consisting of front sensor arrays, side sensor arrays and rear sensor arrays. Front and rear sensors use perpendicular arrays, and side sensors use parabolic or hyperbolic arrays (Fig. 2).

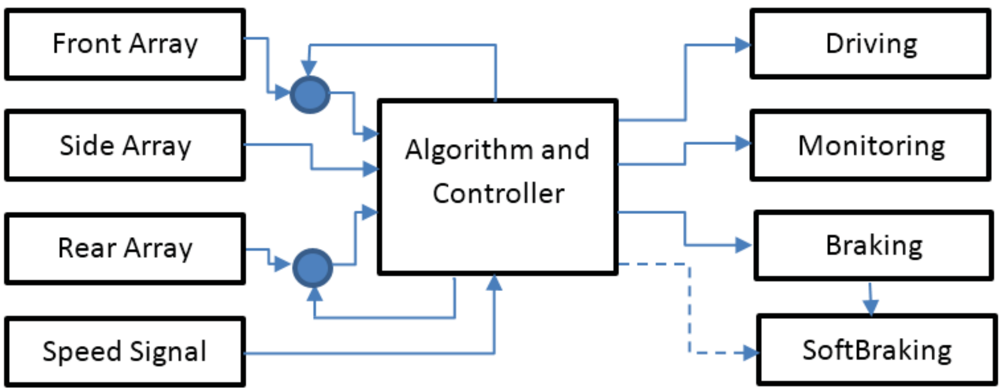

Figure 1. Diagram of the system

The front sensor range and rear sensor adaptively adjust to speed. The faster vehicle's speed makes the higher range of sensor, that performed by adjusting the maximum capability of the ultrasonic sensor. If there is a barrier object detected, the system will act braking by considering objects distance behind the vehicle. The adaptive control system uses an artificial neural network algorithm that allows to increase the range of the detector if the vehicle speed increases. Let Fig. 5 show us the system process flowchart.

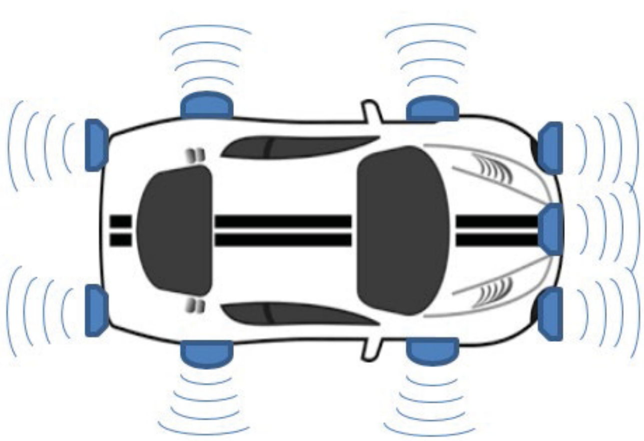

Figure 2. Ultrasonic detectors placement

As the detectors we use two types of ultrasonic sensor, they are HRXL MaxSonar MB7363 for front and rear detectors, and HRLV MaxSonar EZ0 MB1003 for side detectors. For front and rear detectors, the sensor range can be adjusted by modifying the sensor voltage between 2.7 volts to 5.0 volts adapted to speed information of vehicle. While side detector is adjusted in single range and voltage. [17],[2]

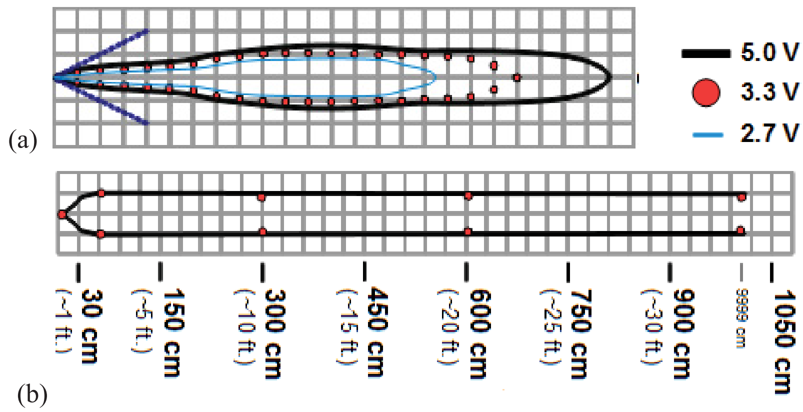

Figure 3. The MB7363 range pattern (a) for shape object and (b) for flat object

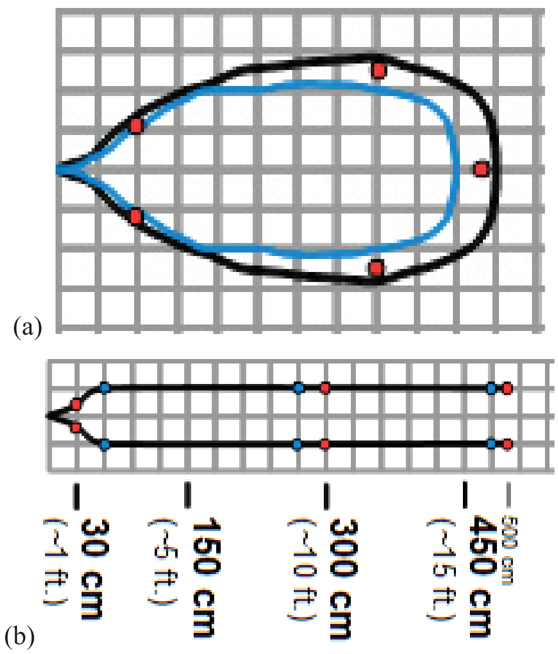

Figure 4. The MB1003 range pattern (a) for shape object and (b) for flat object

Figure 3 shows that the MB7363 sensor can detect flat object up to 10 meters in the maximum voltage of 5 V, and it is about 750 cm maximum to detect shape object. And the MB1003 sensor has a maximum range of 500 cm to detect flat object and about 330 cm of shape object (Fig. 4).

The design of neural network algorithm is adopted to this system and there are some inputs and outputs implemented. As the input layer, some inputs are dominated by ultrasonics sensors that located on: left front, center front, right front, left rear, right rear, front left side, rear left side, front right side, and rear right side. One input is from the speed detector system. In the output layer there are some actions to the system like stop or braking, soft braking, forward left driving, forward right driving, backward left driving, backward right driving, and sensor range controlling.

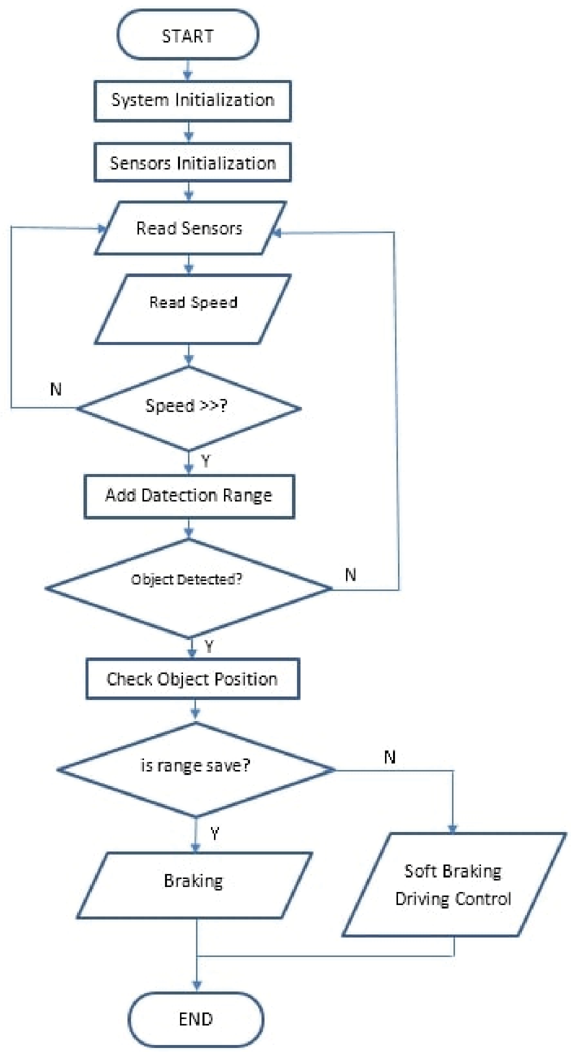

Figure 5. Flow chart of the system

The hidden layer has two parameters to be maintained, there are speed parameter and range parameter. Speed parameter contains fast, middle, slow, forward and reverse. Range parameter lets free, far, middle and near of object detected.

TABLE 1. Neural sets and parameters

Inputs	Parameters	Sub Parameters	Outputs
left front	Range	free	stop or braking
center front		far	soft braking
right front		middle	forward left driving
left rear		near	forward right driving
right rear			backward left driving
front left side	Speed	fast	backward right driving
rear left side		slow	sensor range controlling
front right side		forward	
rear right side		reverse	
speed			

RESULT AND CONCLUSION

To complete and perfecting the previous studies in autonomous vehicle, the design of this system can be adopted to the autonomous vehicle running on urban traffic by implementing ultrasonic sensors to be detector of vehicle's environmental and to avoid collision controlled by Arduino microcontroller with neural network algorithm. The improvement of this study compared to previous study is the dynamic sensor ability to adapt its range to vehicle's speed and the neural network algorithm applied.

FUTURE WORK

Next projects to be done are realization and implementation of the system in real plane that need to accomplish the system by integrating or upgrading the controller to be Raspberry Pi processor and finding the better algorithm of neural network.

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REFERENCES

[1] K. Nonami, M. Kartidjo, K. Yoon, A. Budiyono, *Autonomous Control Systems and Vehicles*, Springer Japan, 2013.

[2] https://www.maxbotix.com/documents/HRLV-MaxSonar-EZ_Datasheet.pdf

[3] A. Luciano P. O. Juan, F. Monica, R Cristina, A. Jesús, O. Victor, "Genetically tuned controller of an adaptive cruise control for urban traffic based on ultrasounds," *Artificial Neural Networks – ICANN 2010*, Vol 6353, pp. 479–485, 2010.

[4] V. V Sivaji, M. Sailaja, "Adaptive cruise control systems for vehicle modeling using stop and go manoeuvres," Int. J. Eng. Resesearch Appl., Vol. 3, No. 4, pp. 2453–2456, 2013.

[5] H. J. Vishnukumar, B. Björn, M. Christian, S. Eric, "Machine learning and deep neural network – Artificial intelligence core for lab and real-world test and validation for ADAS and autonomous vehicles," *Intell. Syst. Conf. London 2017, UK*, pp. 714–721, 2017.

[6] D. Jeon and H. Choi, "Multi-sensor fusion for vehicle localization in real environment," *ICCAS 2015 - 2015 15th Int. Conf. Control. Autom. Syst. Proc.*, pp. 411–415, 2015.

[7] S. Speigle, "Autonomous road vehicle navigation Scott Speigle," *US Army Missile Command. Huntsv. Alabama*, pp. 68–71, 2015.

[8] Y. Takada, E. R. Boer, T. Sawaragi, "Driver assist system for human–machine interaction," *Cogn. Technol. Work*, Vol. 19, no. 4, pp. 819–836, 2017.

[9] K. Song, C. Chen, C. C. Huang, "Design and experimental study of an ultrasonic sensor system for lateral collision avoidance at low speeds," *2004 Symp. Univ. Parma*, no. 3, pp. 647–652, 2004.

[10] K. Takano, "Environment recognition technologies for supporting safe driving," *Hitachi Rev.*, vol. 53, no. 4, pp. 217–221, 2004.

[11] M. Zunjarrao, S. Shirude, "Adaptive cruise control," *Int. J. Eng. Sci.*, pp. 71–74, 2013.

[12] R. H. Madhan, P. K. Priya, "Fully automated cruise control system using ultrasonic sensor," Biomed. Pharmacol. J., Vol. 8, No. 1, pp. 301–306, 2015.

[13] M. A. Rajanikanth, B. G. Kudamble, "Advanced adaptive cruise control system for an automobile," Internatioanal J. Eng. Manag. Res., no. 4, pp. 469–472, 2015.

[14] P. Hosur, R. B. Shettar, M. Potdar, "Environmental awareness around vehicle using ultrasonic sensors," *2016 Int. Conf. Adv. Comput. Commun. Informatics, ICACCI 2016*, pp. 1154–1159, 2016.

[15] J. Yu, S. E. Li, I. Member, C. Liu, B. Cheng, "Dynamical tracking of surrounding objects for road vehicles using linearly-arrayed ultrasonic sensors," *IEEE Intell. Veh. Symp. Gothenburg, Sweden*, pp. 72-77, 2016.

[16] L. Alonso, V. Milanés, C. Torre-Ferrero, J. Godoy, J. P. Oria, T. de Pedro, "Ultrasonic sensors in urban traffic driving-aid systems," *Sensors*, vol. 11, no. 1, pp. 661–673, 2011.
[17] https://www.maxbotix.com/documents/HRXL-MaxSonar-WR_Datasheet.pdf