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Design of Smart Parking System Using Ultrasonic Sensor to Optimize Parking Lots On Campus

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ABSTRACT

Monitoring the availability of parking lots in the campus area is very important. This is related to the solution of the problem of limited parking spaces for four-wheeled vehicles. Existing parking spaces can be optimized by adding a vehicle detection device. This vehicle detection device uses ultrasonic sensors and its programming is based on the ESP32 Microcontroller. Sensitivity parameters measured are object detection distance, influence of other frequencies, influence of passing objects and range areas horizontally and vertically. In the research, the measurement results obtained are object detection distance up to 350 cm, the influence of other frequencies does not exist, passing objects can be detected by vehicle detection devices, range areas vertically up to 250 cm and horizontally up to 150 cm. Based on the test results, the distance reading by the ultrasonic sensor on the vehicle detection device is accurate. This measurement is in accordance with the specifications of the GH-311 type ultrasonic sensor used in the device.

Keywords: Parking System; Ultrasonic Sensor; Sensitivity Measurement; Optimalization parking Lots;

INTRODUCTION

Monitoring system of parking lots availability is very important in the campus area. This is due to the narrow of parking area in the campus and many students used private vehicles. It often happens, there are no more parking spaces left, and traffic jam occurs in the campus. This is exacerbated by the fact. There is no information regarding the availability of parking lots and then the vehicles walk around looking for parking spaces.

Limited parking spaces can be optimized by smart parking system. This system use sensor as a detector of vehicles. The detector is ultrasonic sensor. The ultrasonic sensor is able to interconnecting with ESP32 microcontroller as a main programming. In principle, the sensor works by using the reflection of sound waves from an object in front of it. The detecting results from the sensor can be known whether there is a car in that place or not. The parameters will be measured in this research such as the distance of object detection, the influence of other frequencies, the influence of passing objects and the range of horizontal and vertical areas.

The previous research has been conducted with the aim of creating a system that can make it easier for car parking. The system use ultrasonic sensors and utilizing the AT89S52 microcontroller (Susilo et al., 2021)(Nasir et al., 2020)(Lelono & Muldani, 2009). In previous research, ultrasonic sensors were quite effective in measuring at a distance of 2-300 cm (Mutinda Mutava Gabriel, 2020)(Aliew, 2022).

The novelty has been carried out in this research, namely by using the ESP32 microcontroller. This chip has specifications for Internet of Things (IoT) connections. The measurement results of the sensor detection can be read using a smartphone. It can be designed a car detection device that can provide data with high sensitivity to be applied to smart parking systems. Based on background, the problem formulation is how to make a high sensitivity using the GH-311 ultrasonic sensor and programming based on the ESP32 Microcontroller. The type of car that can be detected such as city car, sedans, MPVs and SUVs.

LITERATURE REVIEW

Ultrasonic sensors work using the principle of sound wave reflection (Ceng Giap et al., 2019). The function of ultrasonic sensor is used to detect the position of an object in front of it. The working frequency of the ultrasonic sensor is 40 kHz to 400 kHz (Karbowiak et al., 2021). This sensor consists of 2 parts, namely the transmitter and

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receiver. If there is a certain object that reflects ultrasonic waves. The reflection waves will be received back by the receiver. Furthermore, the sensor unit in the receiver make the diaphragm to vibrate and the piezoelectric effect produces an alternating voltage with the same frequency (Zhang et al., 2020)(Chakraborty et al., 2021).

An ultrasonic wave is measured by the time parameter required until the arrival of the reflection from a particular object (Ba Hashwan et al., 2023)(Ulyanida et al., 2022). The amount of time required is proportional to twice the distance of the sensor to the object. Based on this principle of sound wave reflection, where the sensor will emit sound waves which catch the reflection back with a time difference as the basis for sensing (Dong et al., 2023)(Anderson, 2021). The time difference between the emitted sound wave and the recapture of the sound wave is directly proportional to the distance or height of the reflecting object.

One of the ultrasonic sensors is the GH-311. This ultrasonic sensor is consist of a 40 KHz frequency signal generation chip, a speaker and an ultrasonic microphone. This sensor detects the distance of an object by emitting ultrasonic waves during a t_{-burst} (200 µs) and detecting its reflection (echo). The GH-311 sensor emits waves controlled from the microcontroller (trigger pulse with a t_{out} min. 2 µs). The measuring range of the GH-311 sensor is from 2 cm to 300 cm. Mechanism of object detection is shown in Figure 1. This sensor has been the choice for all types of industrial needs. It caused by this sensor can be applied for indoor and outdoor purposes and the performance of this sensor is not significantly affected by light, smoke, dust, and color.

Based on this principle, an ultrasonic wave is measured by the time parameter required until the arrival of the reflection from a certain object. The amount of time required is proportional to twice the distance of the sensor to the object. The sensor will emit sound waves which then catch the reflection back with a time difference as the basis for sensing. The time difference between the emitted sound wave and the recapture of the sound wave is directly proportional to the distance or height of the reflecting object. According to the mechanism, the formula to calculate detect spae is shown in equation 1.

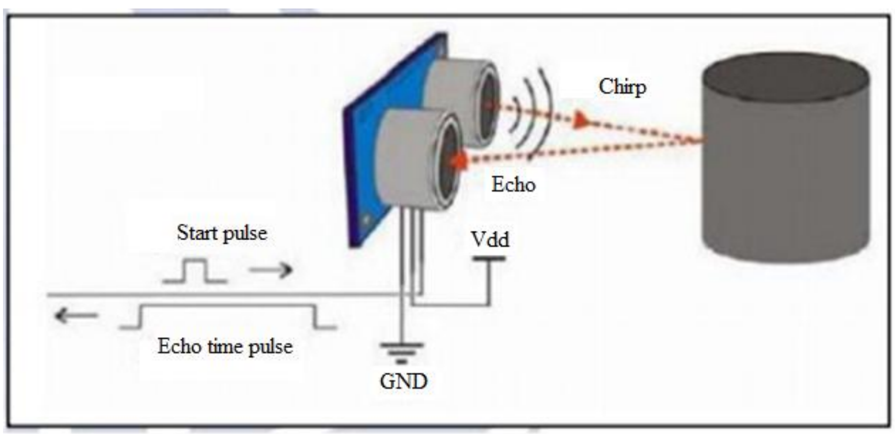

Fig. 1. Detect mechanism of ultrasonic sensor

$$S = \frac{v\,.\,t}{2} \text{.....} \ (1)$$

Explaination:

S = space (m)

v = velocity of sound (344 m/s)

t = echo pulse (µs)

To determine the value of precision sensor can be calculated through the following equation 2. Precision error (e) is a sensor failure in displaying the same distance measurement value under the same conditions. The precision value shows the GH-311 ultrasonic sensor is able to provide almost the same distance measurement results when detecting objects. The following is a graph of the sensitivity of the GH-311 sensor as shown in Figure 2.

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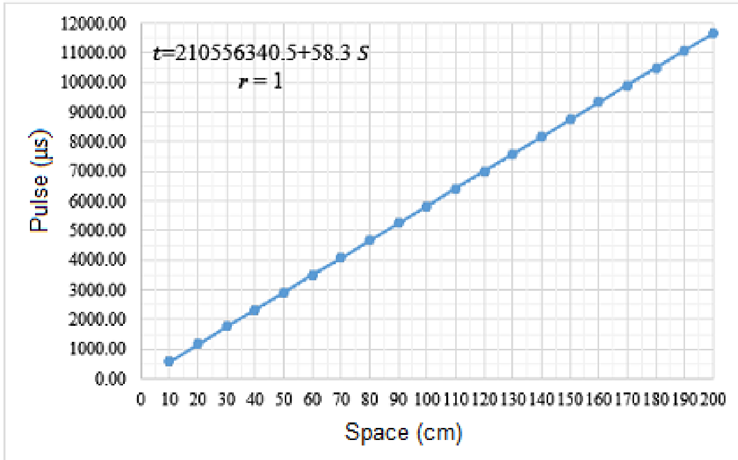

Fig. 2. Graph of sensitivity of GH-311 sensor

In this study, programming was done by The ESP32 microcontroller. This is a dual-core microcontroller consisting of two Harvard Xtensa LX6 CPUs, where all embedded memory, external memory and peripherals location on the data bus of the CPU. In addition, the ESP32 has fast Wi-Fi, more GPIOs, and supports Bluetooth and energy efficiency (Abdellatif et al., 2023).

The ESP32 microcontroller is widely used for Internet of Things connections (López & Lamo, 2023)(Abbas, 2019). Based on this data, there are 34 pins out of GPIO (Gate Peripheral Input Output) on the ESP32 which can be used for connection to ultrasonic sensors as a vehicle detection component and also has wi-fi embedded in the microcontroller. This is suitable for Internet of Things applications. The GPIO of ESP32 microcontroller is shown in Figure 3.

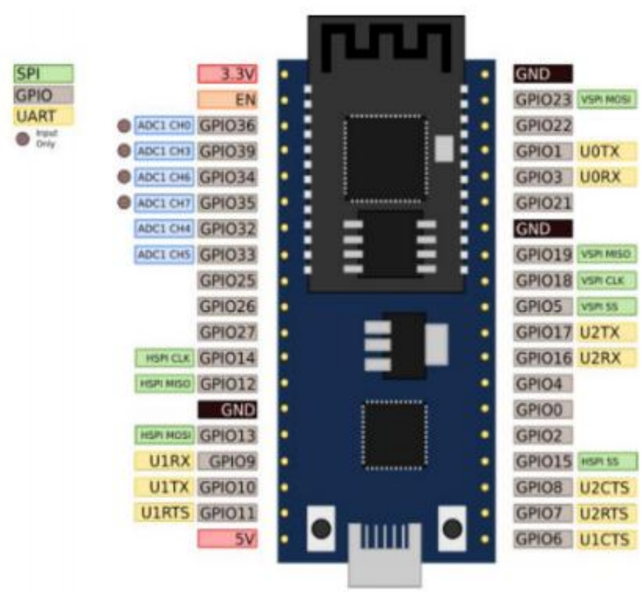

Fig. 3. The GPIO of ESP32

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Tabel 1. Object distance measurement

No	Attribute	Explaination
1	Voltage	3,3 V
2	Processor	Tensilica L108 32 bit
3	Speed	160 MHz
4	RAM	520 K
5	GPIO	34
6	ADC	7
7	802.11 support	11 b/g/n/e/i
8	Bluetooth	BLE (Bluetooth Low Energy)
9	SPI	3
10	I2C	2
11	UART	3

The previous research of smart parking using ultrasonic sensor has done. The research is IoT based smart parking model using Arduino UNO with FCFS priority scheduling. In this research, develop a suitable method to handle parking problem in the crowded big city according to the demand and number of parking slots available. The system gives priority to the users with help of smart parking system. This study proposed Internet of Things-(IoT) based the Arduino UNO model in implementation. This proposed model helps users to allocate booking users vehicles parking free available slot as per time to time availability in college campuses during technical fest in different parking slots and locations (Allbadi et al., 2021).

The other research is using passive infrared and ultrasonic sensors to help to deducting the available parking location and allows to find out for giving priority based on First Come First Serve based (FCFS) scheduling. This model examine the way of the proposed system with utilizing scenarios of various possible ways with FCFS. It show the significance of the parking model using IoT platform. The parking availability detection is capable to find solutions for an empty vehicle parking area for monitoring and reduces users searching time. An automated smart parking model using internet of things, sensing devices and arduino UNO. This system gave priority to users with scheduling model for actual findings parking slots. This system works on real-time to detect all empty parking places based on the internet of things platform. It is helped by sensors and arduino UNO platform. They brought automation to this system on per priority basis to all the users with scheduling techniques. The priority given to users with an automation system is a novelty compared with an existing system. This smart parking is working on real-time basis inputs based on that user demands priority. This is varying to book parking slots with first come first serve preference (Veeramanickam et al., 2022).

The other research is smart parking system using IoT sensors due to the increasing difficulty of finding vacant parking slots in urban cities. This system has been developed to solve the problem parking slots. It is a system that can show the status of all parking slots in an area which allows drivers to find parking easily. The objective of this study is to design a smart parking system by using internet of things (IoT) sensors and evaluate the system's performance. In this study, ultrasonic sensors will be used as the IoT sensors while the microcontroller of the system is the NodeMCU ESP8266. The ultrasonic sensors will be placed in each parking slot to detect the presence of a vehicle. When the sensor detects a car, it will send this information to the microcontroller and the microcontroller will update the parking data stored in the cloud server via an internet connection. The users can access the parking information in the cloud with their mobile devices by scanning the Quick Response (QR) code provided or directly visiting the cloud online. In addition, unique designs are proposed to solve some common problems faced by the parking systems such as the ultrasonic sensor might be malfunctioning and the sensor is unable to differentiate between a vehicle and a pedestrian. The performance of the system will be evaluated based on its accuracy. By the results obtained, the system prototype achieved an accuracy of 100 %. Comparing with other smart parking systems proposed, this system has higher cost-efficiency and reliability. It shows the significant of this research since higher system reliability and cost-efficiency. It can increase the confidence of the parking area owners to implement this smart parking system which can save the driver's time and reduce air pollution (Hong et al., 2023).

The other research is smart car parking system using arduino UNO in the concept of smart cities. The smart parking system consists of an onsite deployment of an IoT module. This is used to monitor and signalize the state of

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availability of single parking space. This study introduce an IoT based coordinated framework for efficient and easy way of parking the vehicles by checking the availability of slots. The system framework comprises of an IoT module utilized to screen and signalize the condition of accessibility of single parking spot. The study additionally depicts an abnormal state perspective of the framework engineering. Towards the end, It examines the working of the framework in type of an utilization case that demonstrates the rightness of the proposed show. The Ultrasonic range detection sensor is utilized with arduino to indicate the empty slot. By measuring the distance using ultrasonic sensor drivers are able to find the empty slot in parking to park the car and help the driver to find the slot easily and reduce the searching time. As the parking place is found to be empty and it is detected using ultrasonic sensors which report it further (Nandyal et al., 2017).

The other research is smart parking management system using SSGA MQTT and real-time database. This system as a part of smart city development has been widely proposed with several research. In this research, proposed a system of parking management application that functions to monitor and control the location of parking slot that can be used by the parking management and parking users. The web application connected to ultrasonic sensor and GPS using MQTT protocol and real-time database. The research used modify algorithm of the SSGA. It is to optimize the allocation of empty parking slot and MQTT protocol to obtain the faster response time of the system when many users are accessing the website application. The results obtain a variation of sending delays from the client publish to firebase at 4 seconds. Meanwhile, for the sending delay from the broker to firebase the variation was at 2 seconds for each time of data sending (Juwita et al., 2020).

The other research is smart parking system mobile application using ultrasonic detector to find an empty parking lot. This research describes the design and development of a prototype of a smart parking system for assisting the vehicle drivers who always experiencing problem in finding indoor parking lots. The objectives of the system are to develop a IoT parking lot system utilizing ultrasonic sensor to detect the presence of a vehicle and to develop a mobile application to display the parking lot layout for assisting car drivers to locate an empty parking lot. For the controller unit, it consists of the Arduino UNO microcontroller which is programmed using JavaScript language. Arduino is used to control the sensor, build a connection with the firebase server and update any changes in the hardware to the firebase. This enables the ultrasonic transmitter and collects the sensing data to be passed to the data transmission and acquisition unit. Once the ultrasonic sensor detects a car, the signal is read and processed by the microcontroller before it is sent to the server to update the status of the parking availability. The accuracy of vehicle detection is 100% with a standard deviation for sensor A0 and sensor A1 are 0.5 and 0.32 respectively. The display result of the parking lot availability is automatically updated in the mobile phone application in real-time (Aziz et al., 2022).

METHOD

Flowchart of the research is shown in Figure 4. The first stage is literature study. The initial step taken at the research stage is to collect various information relevant to the topic of related research. This information collection can be done through internet media, journals or from books.

The second stage is design of hardware and software. In this step, the process of planning and determining everything needed to develop or implement a system is carried out, namely the hardware and software systems needed in designing the system.

The third step is the process of organizing the components of the system so that it can operate effectively. In this research, it is used in designing hardware and software for smart parking system. The fourth stage is to install the required hardware and software. Planning and designing the electronic circuit, including the installation of sensors, microcontrollers, and IoT communication modules. Also plan the mechanical design for smart parking system.

The fifth stage, Testing to ensure all components are functioning properly. Testing includes sensor testing, sorting mechanism testing, data communication testing to the IoT platform, and application testing. If the test results are as expected, then proceed to the next stage. If not, return to the "Tool and Program Design" stage to make improvements and adjustments.

The last stage is analysis of system test results. The last step is to analyze the results of smart parking result according to the sensor detection results. In the form of an explanation of the sensor's work and data transmission to the sensor user.

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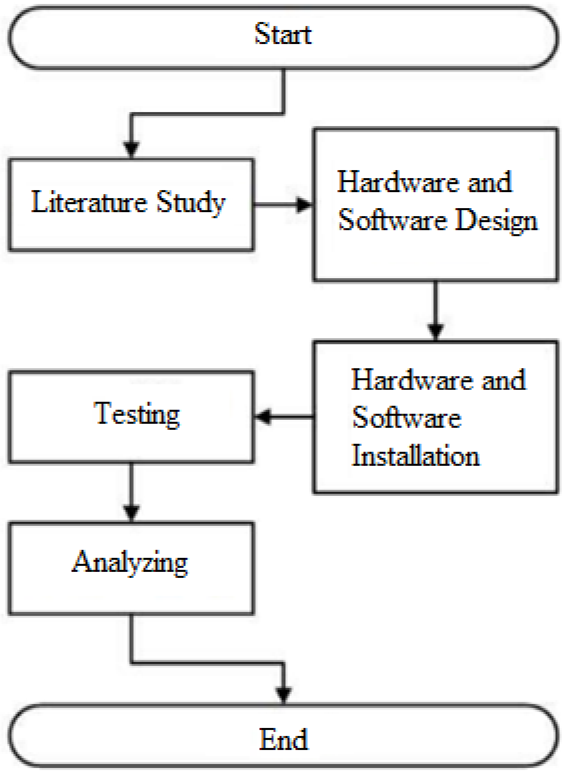

Fig. 4. Flowchart of the research

The device consists of hardware and software. The hardware consists of GH-311 ultrasonic sensor, ESP32 microcontroller and regulatory power supply. Software is programmed by the ESP32 Microcontroller. As an initial detector in this circuit block is an ultrasonic sensor. If there is a certain object that reflects ultrasonic waves, the reflected waves will be received back by the receiver on the ultrasonic sensor. Furthermore, the sensor unit in the receiver will cause the diaphragm to vibrate and the piezoelectric effect produces an alternating voltage with the same frequency. The results of this reading are then processed in the programming on the ESP32 Microcontroller. The regulator block functions as a voltage source for the ESP 32 microcontroller of 3.3 V. The schematic circuit is shown in Figure 5.

This data collection and analysis technique is carried out by applying measurement simulations. There are 4 simulation experiments, namely:

1. In the object detection distance measurement experiment, the measurement carried out is to place the car detector on the ground as high as 50 cm. The object is placed in front of the sensor and shifted away from the sensor at certain intervals up to a distance of 400 cm. This experiment was conducted to find the farthest distance the object could be read by the sensor. The measurement simulation can be seen in Figure 6.
2. In the experiment of the effect of other frequencies, the measurement carried out was to place the car detector on the ground at a height of 50 cm. The object is placed in front of the sensor and shifted away from the sensor at certain intervals up to a distance of 400 cm. The ultrasonic sensor is interfered with another frequency of 40 KHz coming from an android cellphone with the frequency generator application. This experiment was conducted to find out the effect of other frequencies on the measurements of the device. Measurement simulation can be seen in Figure 7.
3. In the experiment of the influence of objects passing by, the measurements taken are the distance of measuring objects at 50 cm and 150 cm. The object used is a human running right in front of the sensor. This experiment

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was conducted to find out whether the tool can detect objects that are passing by. Measurement simulation can be seen in Figure 8.

4. In the range area measurement experiment, the measurements taken are measurements of the range area of the car detection device vertically and horizontally. Range area measurements are used to determine the type of car to be detected. In this experiment, the dimensions of the type of car must be known. The standard dimensions of the car are height x width x length and are Sedan citycar = 151 x 169.5 x 377.5 cm, SUV = 169.5 x 170.5 x 443.5 cm, and MPV = 132.7 x 173.5 x 477 cm. Vertical measurements are used to determine the car height specifications and horizontal measurements are used to determine the car width specifications. For the vertical measurement, the device was placed 200 cm above the ground. An object with a height of 150 cm (according to the height of the car). This object is shifted away from the sensor to a distance of 400 m. This experiment was conducted to find out how large the range area of the tool vertically. Horizontal measurement, i.e. the device is placed as high as 50 cm above the ground. Object with a width of 170 cm (according to the width of the car). The object is shifted away from the sensor to the left side. This experiment was conducted to find out how large the range area of the tool horizontally. The measurement scheme can be seen in Figure 9.

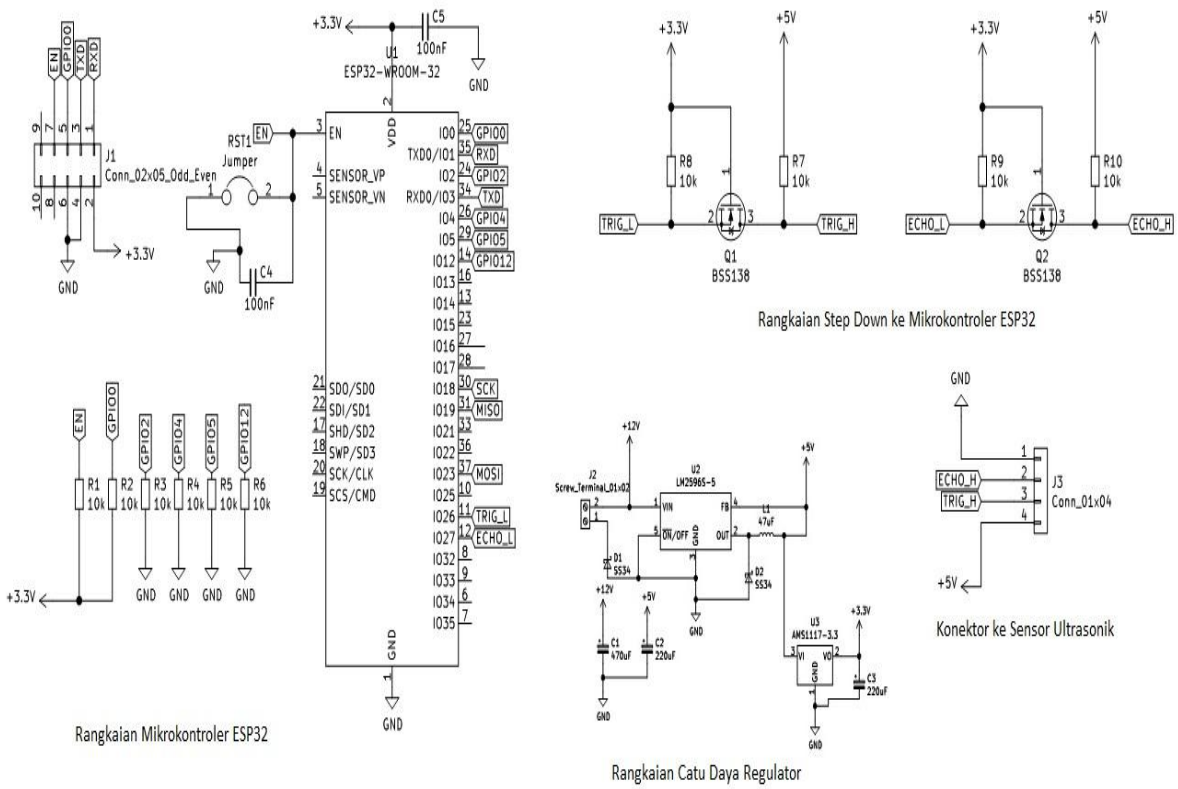

Fig. 5 The schematic circuit

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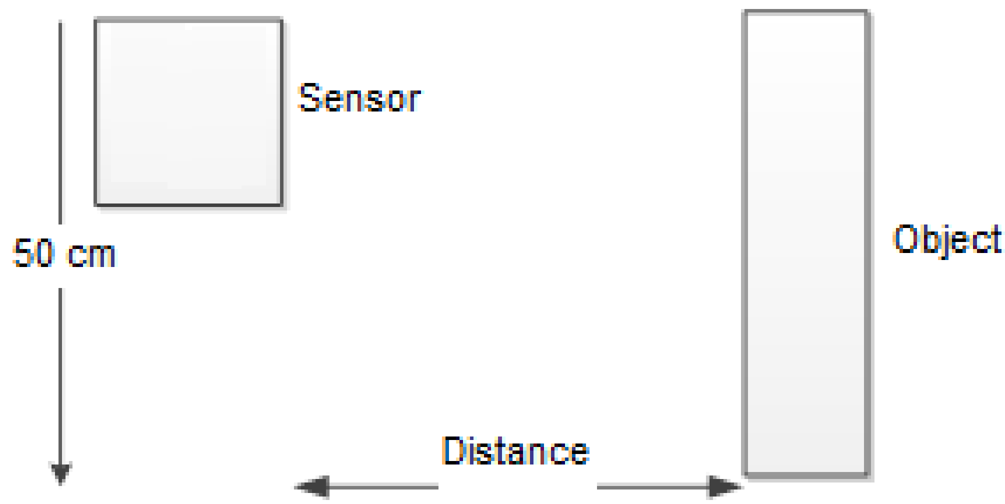

Fig. 6 Object distance experiment

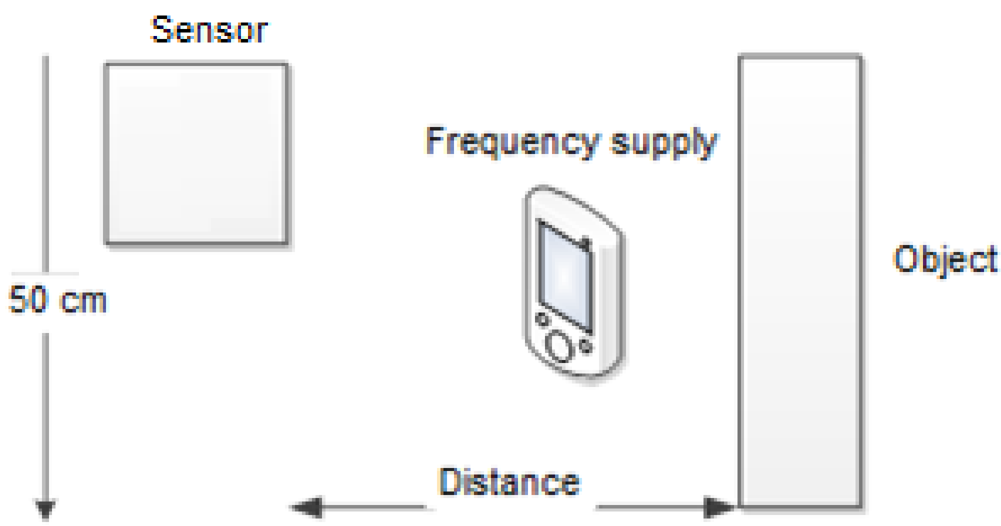

Fig. 7 Frequency's inferences experiment

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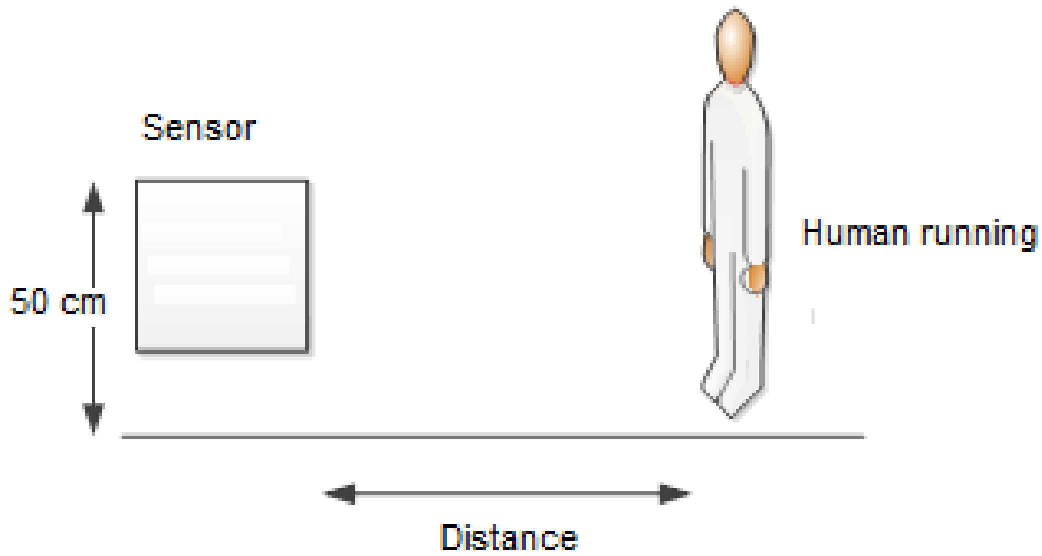

Fig. 8 Human movement experiment

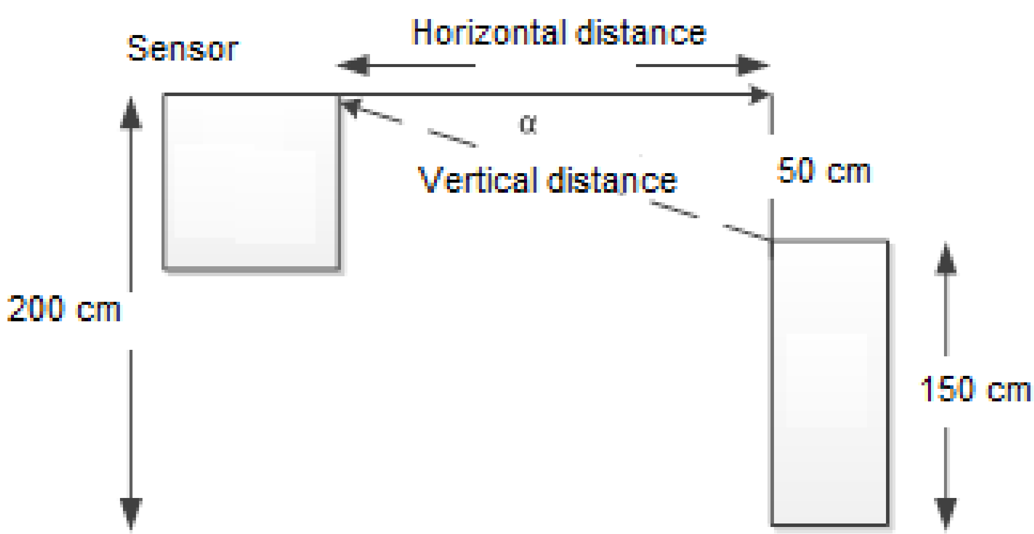

Fig. 9 Vertical coverage area experiment

RESULT

In this section, it can explain the result of parameters measurement such as distance, frequency, inferences, and coverage area sensor.

Tabel 1. Object distance measurement

Testing	Object distance (cm)	Status

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1	10	Detected
2	25	Detected
3	50	Detected
4	100	Detected
5	150	Detected
6	200	Detected
7	250	Detected
8	300	Detected
9	350	Detected
10	400	Not Detected

Tabel 2. Frequency inferences measurement

Frequency (KHz)	**Object distance (cm)**	**Status**
40	10	Detected
40	25	Detected
40	50	Detected
40	100	Detected
40	150	Detected
40	200	Detected
40	250	Detected
40	300	Detected
40	350	Detected
40	400	Not Detected

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Tabel 4. Object movement inferences measurement

Testing	Object distance (cm)	Status
Human movement	50	Detected
Human movement	150	Detected

Tabel 5. Coverage area measurement

Testing	Object distance (cm)	Status
1	10	Detected
2	25	Detected
3	50	Detected
4	100	Detected
5	150	Detected
6	200	Detected
7	250	Detected
8	300	Not Detected
9	350	Not Detected
10	400	Not Detected

Tabel 6. Range Area Sensor Horizontal

Testing	Object distance (cm)	Status
1	10	Detected
2	25	Detected
3	50	Detected
4	100	Detected

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5	150	Detected
6	200	Not Detected
7	250	Not Detected
8	300	Not Detected
9	350	Not Detected
10	400	Not Detected

DISCUSSIONS

Based on Table 1, the object can still be detected up to a distance of 350 cm. Above the value, object can no longer be detected. Based on Table 2, these measurement results are in accordance with the specifications of the type of ultrasonic sensor used, namely the GH-311 type with a range of up to 300 cm. Based on Table 3, the measurement results are not affected by the presence of other frequencies. Based on Table 4, passing objects can be detected by the sensor because they are still within a distance of 50 cm and 150 (below 400 cm).

Based on Table 5, the object can only be detected up to a distance of 250 cm. The maximum angle α (vertical range area angle) is 41.7^o . Then,

$$Vertical\ distance = \frac{Distance}{Cos\ 41.7} \quad (1)$$

$$Vertical\ distance = \frac{250\ cm}{0.74}$$

$$Vertical\ distance = 337.8\ cm$$

Then the vertical distance of 337.8 cm is still within the range of the ultrasonic sensor on the vehicle detection device. For object distances above 250 cm, it cannot be detected because it is out of the range of the tool. This experiment was conducted to determine how large the horizontal range area (x-axis).

Based on Table 6, the object can only be detected up to a distance of 150 cm. The maximum angle θ (horizontal range area angle) is 57.2^o Then,

$$Horizontal\ distance = \frac{Distance}{Cos\ 57.2} \quad (2)$$

$$Horizontal\ distance = \frac{250\ cm}{0.54}$$

$$Horizontal\ distance = 277.7\ cm$$

Then the horizontal distance of 277.7 cm is still within the range of the ultrasonic sensor on the vehicle detection device. For object distances above 150 cm, it cannot be detected because it is outside the range of the sensor.

CONCLUSION

Based on the test results, the distance reading by the ultrasonic sensor on the vehicle detection device is accurate. This measurement is in accordance with the specifications of the GH-311 type ultrasonic sensor used in the device.

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Simulation measurements in the form of object detection distance, the influence of other frequencies, the influence of passing objects and the horizontal and vertical range areas are to measure the sensitivity of the device. Furthermore, vehicle detection devices can be used in car parking system. Further research. it will be developed with an android-based car parking lots with monitoring system using internet of things technology.

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