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Smart Blind Stick Design Using HC-SR04 Sensor and ESP 32 Based Water Level Sensor to Improve the Mobility of Blind Persons

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A B S T R A C T

Blind people in Indonesia, who are estimated to number around 3.75 million people, face major challenges in their daily mobility. In the era of technology 4.0, various innovations have been developed to help them, including the use of walking aids such as smart blind sticks. This research aims to design and build a smart blind stick based on the ESP32 microcontroller, which is equipped with an HC-SR04 ultrasonic sensor and water level sensor to detect holes and puddles of water, as well as a vibration module and speaker to provide warnings. The research method used is the prototyping method, which involves collecting system requirements, making prototypes, and evaluating users. The research results show that this smart blind stick is effective in providing warnings of obstacles on the road through vibration and sound, as well as making travel easier and increasing the safety of blind people. All main components function as expected, making this device a practical and innovative solution for improving the mobility of blind people.

INTRODUCTION

Blind people are people who have impaired vision, so that both of their eyes do not function fully like other people. In Indonesia, around 1.5% of the total population is categorized as blind. If in 2019 the population of Indonesia reached 250 million people, then currently it is estimated that there are around 3.750 million blind people in Indonesia, both those who experience total blindness and low vision [1,2,3].

In the era of technology 4.0, which has developed very rapidly, especially in the field of robotics knowledge, humans continue to think about creating something new and thinking about whether it will be useful or not for others and the world. People usually have five senses that allow them to feel changes in the environment outside their bodies. One of them is the sense of sight, or eyes. The sense of sight provides a lot of information to humans [4,5,6].

People with visual impairments, also known as blind people, are one of the groups of people who have special needs that require attention as pedestrians. Those with low vision or total blindness are two types of blind people [7,8,9].

So far, blind people rely on their hearing to walk, because they usually have good hearing ability. They use various methods, such as using a cane as an aid. Canes are one of the most common tools used by people with visual impairments. Canes for the blind are generally divided into two types: long canes and folding canes. Long canes are made according to established standards, while folding canes are more practical because they can be folded when not in use. However,

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folding canes are less effective for blind people because they are less sensitive and strong in use. In addition to canes, there are several other high-tech assistive devices available for blind people [10,11,12].

Smart Blind Stick is a device specially designed to help them navigate and prevent collisions with obstacles. By using two HC-SR04 ultrasonic sensors, this smart blind stick can detect holes and obstacles around it. When there is an obstacle in front, the sensor will measure the distance and send an audible warning through the speaker [13,14,15].

This device provides significant benefits to visually impaired people by improving their walking experience. Previously, there were many cases where they had difficulty seeing holes, both shallow and deep, which often caused them to fall. This device is designed to overcome this problem by giving an automatic vibration alert when it detects a hole in the ground. In addition, with an active sound warning system when it detects an obstacle ahead, this device helps reduce the risk of accidents caused by obstacles on the road. Thus, this device not only makes it easier for visually impaired people to travel, but it can also reduce the possibility of injury due to holes and obstacles in their path.

Some previous studies are the Making of Smart Shoes for the Blind. The disadvantage of this tool is that it is uncomfortable with the placement of the tool on the shoe [16,17]. Further research developed technology to help the Blind recognize Rupiah banknotes using Color Sensors [18,19]. Then gloves for the Blind using ultrasonic sensors [20,21]. Researchers created this tool to provide significant benefits for the Blind by improving their walking experience. Previously, there were many cases where they had difficulty seeing holes, both shallow and deep, which often caused them to fall.

Therefore, in this study a smart blind stick was designed that has a push button that functions as an on/off button for the device, this stick uses an ESP32 microcontroller as a processor of the entire smart blind stick component process will give an automatic vibration signal using a vibration module when the ultrasonic sensor HC-SR04 and water level sensor detect holes in the ground and puddles on the path being passed. In addition, with an active voice warning system through the speaker module and df player mini when detecting obstacles in front, this tool helps reduce the risk of accidents caused by obstacles on the road. This tool is also designed with the use of wheels to make it easier for blind people to walk. Thus, this tool not only makes it easier for blind people to travel, but can also reduce the possibility of injury due to holes, puddles and obstacles in their path.

METHOD

HC-SR04 Ultrasonic Sensor

An ultrasonic sensor is an electronic device that can convert electrical energy into mechanical energy through ultrasonic sound waves. The HC-SR04 sensor consists of two main parts: an ultrasonic transmitter, which functions as a transmitter, and an ultrasonic receiver, which functions as a receiver. The range of distances that can be measured by this sensor ranges from 2 cm to 400 cm, with an accuracy level of 0.3 cm. This sensor has the ability to detect objects with a maximum angle of no more than 15°. The current consumption required by this sensor does not exceed 2mA, and the voltage required is +5V. The HC-SR04 sensor has four pins used in its operation [22,23].

The Ultrasonic Sensor has 4 pins, namely:

1. The VCC pin functions as a pin to input voltage.
2. The GND pin functions as grounding.
3. The Trigger pin is used to trigger the output of the signal.
4. Echo pin is used to receive reflected signals from objects.

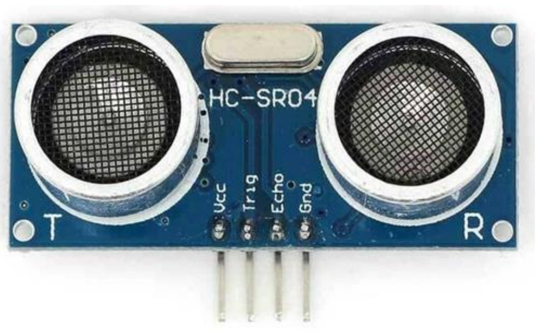

Figure 1. Ultrasonic Sensor HC-SR04

The specifications of the HC-SR04 ultrasonic sensor are as follows:

1. Dimensions: 45 mm (L) x 20 mm (W) x 15 mm (H)
2. Operating voltage: 5 VDC
3. Standby current: less than 2 mA
4. Detection current: 15 mA
5. Sound frequency: 40 kHz
6. Maximum range: 400 cm
7. Trigger input: TTL level pulse with a minimum duration of 10µS
8. Echo pulse: Positive TTL level signal, with a width proportional to the detected distance.

Water Level Sensor

A Water Level Sensor is a device used to provide a signal to an alarm panel or automation when the water level reaches a certain level. This sensor will send a dry contact signal (NO/NC) to the panel. To detect the height of the water, this sensor uses a voltage value reading generated by several voltage division circuits consisting of four outputs [24,25].

Figure 2. Water Level Sensor

Tool Design and Specifications

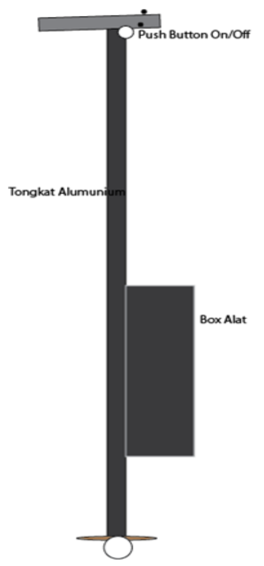

Figure 3. Tool Prototype Design

The specifications of the device created are as follows:

1. The input voltage on the ultrasonic sensor is 5V.
2. The input voltage on the water level sensor is 3.3V.
3. By using the HC-SR04 ultrasonic sensor, it detects obstacles with a maximum distance of 400 cm. In this designed device, the distance is limited to a maximum of 50 cm.
4. The resolution of the ultrasonic sensor is 1 cm and the detection angle is 15 degrees.
5. Can detect puddles of water using the water level sensor.
6. ESP 32 as a data processor.
7. Output from sensor reading results is done with speakers and vibration modules.
8. Using wheels for easy mobility.

Wiring Design Tool

The following is a series of cables between all the components of the materials used to make the smart blind stick:

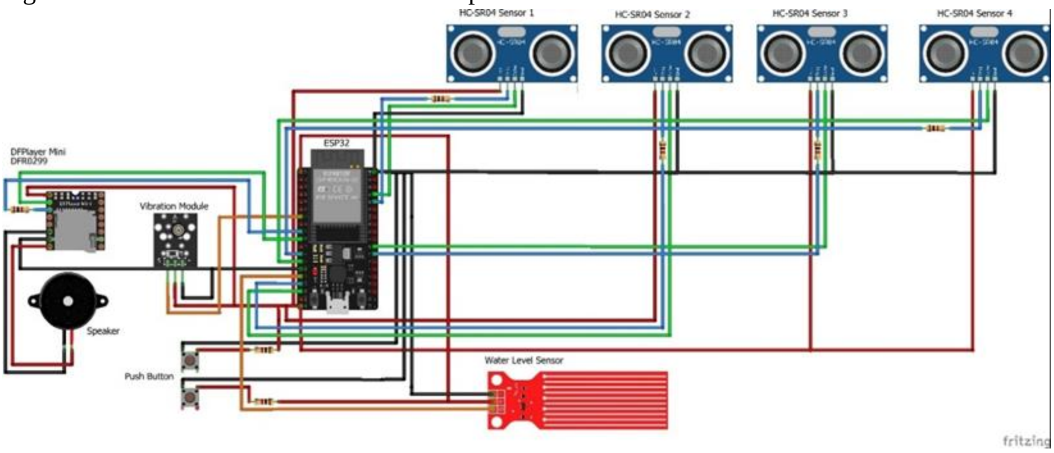

Figure 4. Circuit Schematic

The components in the image above are as follows:

1. Esp 32
2. Ultrasonic Sensor HC-SR04
3. Water Level Sensor
4. Jumper Wire
5. Speaker
6. DF Mini Player
7. Push Button
8. Vibration Module

RESULTS AND DISCUSSION

In this testing phase, the first step is to ensure that each component and circuit used is functioning properly. Next, check each connection between components to ensure that everything is connected correctly according to the circuit schematic. Testing includes several aspects, namely testing the HC-SR04 ultrasonic sensor to detect obstacles and holes, testing the water level sensor, and testing the speaker and vibration module.

Tool Design Results

This chapter will explain the results of the smart blind stick design that has been made. This tool is designed to help blind people carry out their daily activities more safely and comfortably.

This smart blind stick is equipped with various components that function to provide warnings about various obstacles on the road. The main components used in the design of this tool include the ESP32 microcontroller, HC-SR04 ultrasonic sensor, water level sensor, vibration module, speaker module, and DFPlayer Mini. In addition, this tool is also equipped with wheels to make it easier for users to walk.

Figure 5. Tool Design Prototype Results

Figure 6. Wiring Tool Design Results

HC-SR04 Ultrasonic Sensor Testing

HC-SR04 ultrasonic sensor testing was carried out by placing various objects at different distances in front of the sensor with a maximum range limited to only 50 cm - 70 cm. The aim is to measure the accuracy of the sensor in detecting distance and its response speed. The test results show that the sensor can detect objects at varying distances with high accuracy. The sensor is able to provide accurate distance data to the microcontroller, which is then processed to provide audible warnings to the user via the speaker module and DFPlayer Mini.

Table 1. HC-SR04 Ultrasonic Sensor Test Results

No	Detection Distance	Front Ultrasonic	Left Ultrasonic	Right Ultrasonic	Bottom Ultrasonic
1	10 Cm	Active	Active	Active	Inactive
2	20 Cm	Active	Active	Active	Inactive
3	30 Cm	Active	Active	Active	Inactive

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4	40 Cm	Active	Active	Active	Active
5	50 Cm	Active	Inactive	Inactive	Active
6	60 Cm	Active	Inactive	Inactive	Active
7	70 Cm	Inactive	Inactive	Inactive	Active

Based on the test data, it can be seen that in the range of 10-50 cm All Ultrasonics are active in detecting existing obstacles. Then from a distance of 60-70 cm the active sensor is only the lower ultrasonic sensor that will detect holes.

Water Level Sensor Testing

The water level sensor was tested by placing it on a dry surface and then on puddles of water with different heights. The test results showed that the sensor can detect the presence of water accurately and give a signal to the microcontroller to activate the vibration module. This test ensures that the user will get a warning when there is a puddle of water on the path they are traveling.

Table 2. Water Level Sensor Test Results

No	Water Level	Test Status
1	0 Cm	Inactive
2	1 Cm	Inactive
3	2 Cm	Inactive
4	3 Cm	Inactive
5	4 Cm	*Water Detected*
6	5 Cm	*Water Detected*

Based on the water level sensor test result data, it can be seen that the sensor is only programmed to detect water levels greater than or equal to 4 cm. The sensor functions normally and the reading data will be sent to the Microcontroller for processing.

Overall System Testing

The overall system test is conducted by integrating all components and testing them in real conditions. The test is conducted by asking blind people to use this smart blind stick in various road conditions, both indoors and outdoors. The test results show that this tool can provide effective warnings and help users avoid obstacles and puddles well.

The overall system test ensures that this smart blind stick can function according to its designed purpose. This tool not only makes it easier for blind people to travel but also improves their safety when walking on roads full of obstacles.

Table 3. Overall System Test Results

Smart Blind Stick Testing						
		Response of All Components				Testing Status
No	**Condition**	**Ultrasonic Sensor**	***Water Level Sensor***	***Vibration Module***	***Modul Speaker dan Df Player Mini***	
1	Obstacle Ahead	Detected	Inactive	Active	Active	Success
2	Obstacle Left	Detected	Inactive	Active	Active	Success
3	Obstacle Right	Detected	Inactive	Active	Active	Success
4	Hole detected	Detected	Inactive	Active	Active	Success
5	Water detected	Detected	*Water Detected*	Active	*Active*	Success

Based on the Test Data above, all components in the Smart Blind Stick function well and are as expected by the researcher.

CONCLUSION

After the design, testing, and analysis of the results, several conclusions can be drawn from the research and development of this smart blind stick: This tool successfully provides effective warnings of obstacles on the road, such as potholes and puddles, through vibration and sound. Users can easily detect obstacles in their path. All major components, including the ESP32 microcontroller, HC-SR04 ultrasonic sensor, water level sensor, vibration module, speaker module, and DFPlayer Mini, function properly and as expected. This smart blind stick not only makes it easier for blind people to travel, but also improves their safety by providing early warnings of obstacles on the road.

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