Design Prototype of Audio Guidance System for Blind By Using Raspberry Pi and Fuzzy Logic Controller

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Abstract—With almost 3.75 million people with visually impaired in Indonesia, according to statistical data shown that most of them not live in prosperity. To increase their productivity they need an assistive device that's allows them to navigate freely. This paper presents a novel Audio guidance system for blind in the shape of simple bag with earphone for giving them an audio guidance efficiently and safety. Different with other audio guidance, we propose a simple system consist of Raspberry Pi Camera and Ultrasonic Sensor as input, Raspberry Pi, Earphone and Power bank. This system is initiated by providing a voice command of the direction where the blind person must walk or go through, so they can avoid from obstacles. We also apply Fuzzy Logic Controller (FLC) to detect the obstacles along they walk by using 3 ultrasonic sensors. The experimental result shows that by using FLC and interfacing by Raspberry Pi the proposed system can effectively to detect the obstacles and give direction with 2.32% distance error.

1. Introduction

According to the Indonesian Ministry of Social Affairs, it is estimated that the population with disabilities in Indonesia is 3.11%, according to data from the Ministry of Health giving a figure that is more than 6% [1], and According to Cendana News.com Daily on April 29th, 2017 which states that 250 million people in Indonesia almost 1.5 percent or 3.75 million with visually impaired, on average they are still underprivileged because of the lack of access to education for them, besides that, their limitations on vision also caused their productivity to be very limited, which also affected to their poor welfare.

In order to increase their productivity, several studies have been carried out in order to create an aids for the blind such as assistive device that's allow them to navigate freely. For an example a study about sensor wand for the blind, finger read to read writing, bionic eye which is a camera embedded in the retina, ultracane is a stick that works like a bat and so on. However, these products are still relatively expensive and not easily available. Therefore many innovations are made to produce products that are affordable by the Indonesian people in particular. In 2014, By using Embedded system like Arduino, Raspberry Pi ang GPS technologies, Muhammad Adib was created The smart stick is called Combo Cane, where this product will guide users through voice to earphones by using the Bluetooth network[2]. However, the cost needed to make this prototype is approximately 1.5 million rupiah.

Tripathi (2014) by using Raspberry Pi created an electronics guidance for the navigation of visual impared person, This study was using web camera as human detection and ultrasonic sensor as objects detection, and the output was a sound beep through the earphone. The product was formed as a belt containing the Raspberry Pi board, sensors and web cameras with weigh around 500 grams[3]. However the blink must use the belt where ever they go.

In 2015 Farhan AA was created Designing and Implementing of A Blind Tool Using Ultrasonic Sensors and Global Positioning System (GPS), In this study they use HC-SR04 as Ultrasonic Module and GPS also that will informed the coordinate of the blind. The output of this study was a buzzer and SMS Text[4]. In 2017 Gharat M was created Audio guidance system for blind, in this study was implemented RFID technology, Speech Sensor Module and Ultrasonic Sensor also. Output of this study

Audio Navigation System[5]. After we learned the previous studies about assistive device for the blind, Finally we decide to create a new type of Audio guidance system for blind by using Haar-Like Feature as human detection and also Fuzzy Logic Controller as Navigation System for the blind. We hope with this product blind people can do their activity or work independently, so they can making some money to increasing their welfare.

2. Previous Study

Electronic Travel Aids (ETA) had been developed by Tripathi (2014) which is intended for blind people, the product that had been developed in the form of belts, inside the belt consists of, Raspberry Pi, Ultrasonic sensor and Web Camera, that why the belt has 500 grams of weigh [3]. Web camera has functions as a human detection for the blind people (user). The web camera captured images from humans using the Haar Like Features application. The ultrasonic sensor detected distance of the obstacle and detected the other object also that wasnot detected by Haar application, the output produced was the sound beep that can be heard through the earphone. The disadvantages of the product has 500 grams weight despite the advantages of it that both hands of the user free.

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In 2017 Gharat M was created Audio guidance system for blind, in this study was implemented RFID technology, Speech Sensor Module and Ultrasonic Sensor also. Output of this study an Audio Navigation System[5]. In this study they implemented Raspberry Pi as interfacing module, and HC-SR04 as obstacle detection. However in this study they implemented Speech Sensor Module also where The desired destination is given as input by the blind person in this case the destination it is a room of the certain building for example school.

Table 1 below explained the comparison between previous studies with the proposed design. Based on previous study we decide to implement some part that already used it, to composed The proposed design we must consider the easyness of the user to use it and effective of the system to give navigation for the blind. the comparison between proposed design and previous study as follows:

Table 1. Comparison between Proposed Design and Previous Study

No.	Part's Composition	Tripathi (2014)	Farhan AA (2015)	Gharat M (2017)	Proposed
1.	Interfacing System	Raspberry Pi 1 Model B+	Microcontroller AT Mega	Raspberry Pi 2 Model B	Raspberry Pi 2 Model B
2.	Obstacle Detection	Web Camera, Ultrasonic Sensor	GPS, Ultrasonic Sensor	RFID Ultrasonic Sensor, Speech Sensor Module	Raspberry Pi Camera Ultrasonic, Sensor
3.	Power	5V, 2A DC Adapter	5V, 2A DC Adapter	Power Bank 1000m ah, 5V	Power Bank 15000m ah, 5V
4.	Output	Beep	Buzzer SMS Text	Audio Navigation System	Audio Navigation System

In 2017 Bai J, Lian S, and friends was created Smart Guiding Glasses for Visually Impaired People in Indoor Environment [6]. In this study they implemented eyeglasses with multi-sensor fusion based obstacle avoiding algorithm is proposed, which utilizes both the depth sensor and ultrasonic sensor to solve the problems of detecting small obstacles, and transparent obstacles.

As shown in Table 1 proposed design consist of Raspberry Pi Camera and ultrasonic Sensor as input, Raspberry Pi as Interfacing System, power bank and earphone as output navigation system. Different with other study the navigation system will show the direction more specific. Proposed design implemented 3 pcs of ultrasonic sensors. These sensors has function to show the direction (right, left, straight).

Before discussion about the model of proposed design, earlier will be explained in the following sub-chapters are hardware (Raspberry Pi, 5 MP Raspberry Pi Camera, Power Supply, and earphones) that will be used in preparing the planned product. Next, we will explain the applications used in detecting obstacles in this study, namely the Haar Like Feature and Hough Line Transform applications

3. Proposed Design Model

Figure 1 shows block diagram system of proposed design model which consist of 3 pcs ultrasonic sensor, raspberry Pi camera, Raspberry Pi, Power System and earphone.
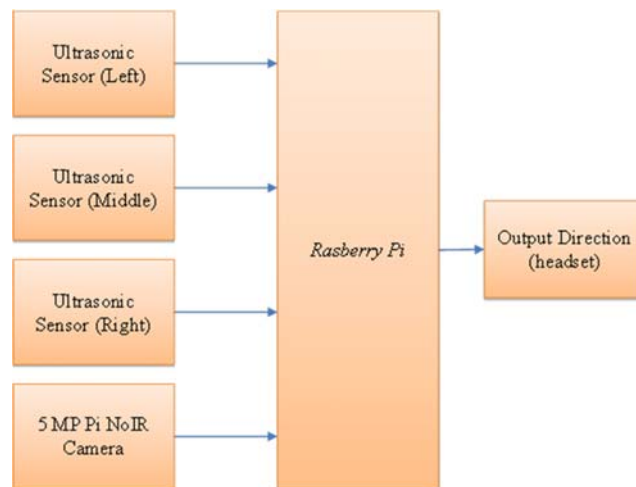

Figure 1. Block Diagram Proposed Design Model

Before discussion about the model of proposed design, earlier will be explained in the following sub-chapters are hardware (Raspberry Pi, 5 MP Raspberry Pi Camera, Power Supply, and earphones) that will be used in preparing the planned product. Next, we will explain the applications used in detecting obstacles in this study, namely the Haar Like Feature and Hough Line Transform applications

3.1. Interfacing System

Embedded systems are another form of mini computer that is able to work according to the commands or programs that are planned in it. At the beginning of its development, this system is represented by a microprocessor for example Z log series , then the AT Mega series, then Arduino series and the most recent is the Raspberry Pi. Raspberry Pi has better specifications than the Arduino series as shown the below table:

The advantages of Raspberry Pi 2 B model are: 1). Quad Core Processor with ARMv7 Architecture, 2). 1 GB RAM Memory, 3). 6 time speed faster than old one, Raspberry Pi 2 Model B is equipped with 8GB NOOBS (New Out of the Box Software) which can be used to process the Raspberry Pi boot process more easily. With considered the above specifications and the advantages of Raspberry Pi 2 B model chosen as a minimum system of the proposed design.

3.2. Raspberry Pi Camera

The sensor used in this study is the 5 MP Raspberry Pi Camera. which has the ability to present images 2592 x 1944 pixels and 1080 pixels video at 30 frames per second, 720 pixels at 60 frames per second and 480 pixels at 90 frames per second. Another advantage of this camera is 25 mm x 20 mm x 9 mm with a weight of about 3 grams.

The Raspberry Pi camera consists of 2 types, 1). Pi IR (infrared) , and 2). NoIR (no infrared) cameras. For human detection, both cameras can be used during the day, but Pi NoIR cameras usually have advantages that can be used in low lighting conditions (dark) because they are not equipped with infrared. From the results of the study that Pi NoIR camera has been able to use to recognize human faces at night well, therefore in this study the 5 MP camera with Pi NoIR chosen, beside that this camera lighter than web camera.

3.3. Ultrasonic Sensor

In this study, ultrasonic sensor HC-SR04 was chosen because of the lower price and because of its far range compared to the ping type sensor. Sensor range according to datasheet from 3 cm - 3 meters (ping) and 2 cm - 4 meters (HC-SR04) [9]. The interfaces of these two sensors differ in the number of I / O pins, but in fact the principle of detecting the ultrasonic signal is the same.

Based on these previous studies shown that some of them was implemented ultrasonic sensor as obstacle detection and the result the studies shown good accuracy. In this study 3 pcs of ultrasonic sensor implemented which each sensor represented the direction "Left", "Middle" and "Right".

3.4. Headset or Earphones

Headsets or Earphones used in this study do not require special specifications, provided they are able to provide sound output.

3.5. Power Supply

Raspberry Pi can use a micro USB power connection (5V 1A DC) or with an external power supply. Therefore in this study the power bank with specifications 15000mAh, 5V, 1A. Consideration of using this power bank as follows:1). The Power Bank can top up the battery, 2). The shape is flexible and easily available, 3). The specifications can be changed depending on usage, the greater the capacity of the power bank the longest the guide tool can be used.

3.6. Haar-Like Features

Haar-like feature is one of some methods in image processing for object recognition or human detection. Haar-like feature uses a rectangular (square) feature, which gives a specific indication of an image. The idea of Haar-like Features is to recognize an object based on the simple value of a feature rather than based on the pixel value of the captured object image [7].
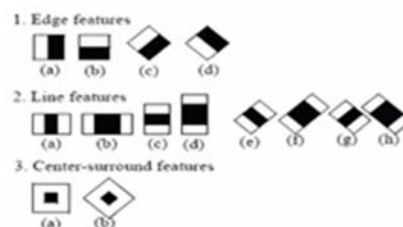

Figure 2. Box Combination of Haar [7]

Haar The feature used by Viola Jones (2003) based on the Haar wavelet is a single square wave (one high interval and one low interval) [8]. For two dimensions, one light and one dark. Furthermore, box combinations used for better visual object detection are shown in Figure 2 as above.

The haar-like feature value is obtained from the difference in the number of pixel values in the dark region with the number of pixel values in the bright area, can be seen in the following equation 1:

$$F(Haar) = \sum Fwhite - \sum Fblack \qquad (1)$$

Whereas *F(Haar)* is the total feature value; $\sum$ *F white* is a feature value in bright areas; and $\sum$ *F black* is a feature value in dark areas.

4 concepts in object detection according to Kusumanto (2012), are explained as follows; 1). Training data using two models, a). Positive Sample, contains an image of the object you want to detect; b) Negative Sample, contains an image other than the object you want to detect. 2). A rectangular feature called the Haar feature. Haar feature is a feature based on a single square wave consisting of one high interval and one low interval. In a two-dimensional image, it consists of one light and one dark. So, every Haar-like feature consists of a combination of black and white boxes, as shown Figure 2. 3). Integral image to detect features quickly, then integrated (summed) based on pixel values contained in the image. 4). Multilevel classifiers to connect many features more efficiently.

The Haar-like application featured on Rapsberry Pi has been done by previous researchers Tripathi (2014), the research conducted was able to prove that the Haar-like Feature applied to Raspberry Pi is capable of detecting human objects well, therefore this research will apply Haar-like Feature on Raspberry Pi 2 B model.

3.7. Fuzzy Logic Controller

There are several methods on Fuzzy logic, namely the Tsukamoto, Mamdani and Sugeno methods. The Tsukamoto method represents a fuzzy set with a monotonous membership function. The output of the inference from each rule is the normal set (crisp) that is determined according to its predicate. While the final output is obtained by the average of the weights. The Sugeno method has an output in the form of a linear or constant equation, in contrast to the Mamdani Method which has the output of a Fuzzy set. The Mamdani method is often referred to as the min-max method inferencing. This method uses the min equation in the alpha implication process and the max equation in the aggregation process [10].

The Fuzzy set has 2 attributes, namely: 1). Linguistics, naming a group that can represent a particular condition or condition using natural language, such as "sunny", "rain", "cloudy"; 2). Numerical, a value or number that can indicate the size of a variable such as 40, 25, 50, and so on. There are several things that also need to be known in understanding of fuzzy systems, as follows:

- Fuzzy variables are variables that will be discussed in a fuzzy system. Examples: temperature, age, health, and so on.
- Fuzzy set is a group that will represent a certain condition or condition on a fuzzy variable. For example: temperature variables, divided into 3 fuzzy sets, namely: hot, normal, and cold.
- Universe talking is the overall value that has been obtained to be operated in a fuzzy variable, the universe of discussion is a set of real numbers that always go up or increase monotonically from the left right. The universal value of speech can also be either positive or negative.
- If-then rules can be used to declare a statement in fuzzy logic. This rule is formulated as follows;

$$If\ x\ is\ A\ then\ y\ is\ B \qquad (2)$$

Whereas x was represents the input, while y represents the output. A and B are the linguistic values of x and y. the sentence "x is A" is called antasedent or premise, while the sentence "y is B" is a consequent or conclusion.

One of the things that must be understood in Fuzzy is the membership function. Membership function is a curve that can show the mapping of data input points into the membership function or the membership value that has intervals between 0 to 1 (often referred to as membership degrees). There are 3 type of function approach that use to be used in one Methode, as follows:
1. Linear Representation Function;
2. Triangle Membership Functions;
3. Trapezium Membership Function.

In this study Fuzzy Logic Controller (FLC) was implemented to control 3 ultrasonic sensors. By using Triangle Membership Functions the rule base was formed. The numner of rule base had formed was 27 rule, and the output will be reference to these rule base, see Table 2

Table 2. Rule Base of Proposed Design

Rule No	Sensor Reading			Output
	Left	Middle	Right	
1.	Near	Near	Near	Stand Still
2.	Near	Near	Middle	Right
3.	Near	Near	Far	Half Right
4.	Near	Middle	Near	Straight
5.	Near	Middle	Middle	Right
6.	Near	Middle	Far	Half Right
7.	Near	Far	Near	Straight
8.	Near	Far	Middle	Straight
9.	Near	Far	Far	Straight
10.	Middle	Near	Near	Left
11.	Middle	Near	Middle	Left
12.	Middle	Near	Far	Half Right
13.	Middle	Middle	Near	Left
14.	Middle	Middle	Middle	Right
15.	Middle	Middle	Far	Half Right
16.	Middle	Far	Near	Straight
17.	Middle	Far	Middle	Straight
18.	Middle	Far	Far	Straight
19.	Far	Near	Near	Half Left
20.	Far	Near	Middle	Half Left
21.	Far	Near	Far	Half Left
22.	Far	Middle	Near	Half Left
23.	Far	Middle	Middle	Half Left
24.	Far	Middle	Far	Half Left
25.	Far	Far	Near	Straight
26.	Far	Far	Middle	Straight
27.	Far	Far	Far	Straight

Figure 3 shows Triangle membership function which implemented to the proposed design. As explained before that 3 pcs ultrasonic sensors implemented by using formula 3, 4,and 5, to define membership of Near, membership of Middle and membership of Far.
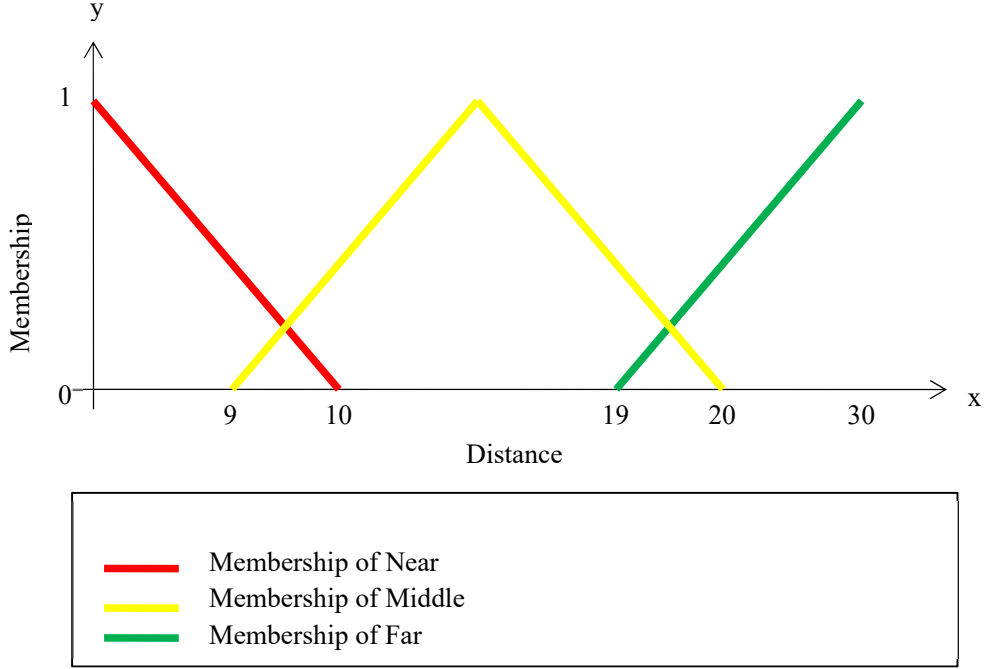

Figure 3. Triangle membership function

$$\mu Near[z] = \begin{cases} 1, & z \leq 0 \\ \frac{100-z}{100}, & 0 < z < 100 \\ 0, & z \geq 100 \end{cases} \qquad (3)$$

$$\mu Middle[z] = \begin{cases} 0, & z \leq 90 \ \cup z \geq 200 \\ \frac{z-90}{55}, & 90 < z < 145 \\ \frac{200-z}{55}, & 145 < z < 200 \end{cases} \qquad (4)$$

$$\mu Far[z] = \begin{cases} 0, & z \leq 190 \\ \frac{z-190}{110}, & 190 \leq z \leq 300 \\ 1, & z > 300 \end{cases} \qquad (5)$$

3.8. Flowchart System
Flowchart system will explain how the system does work as shown at Figure 4. There are 5 steps will necessary for system to determine the navigation system as follows;
1. Turn on the Rasberry Pi.
2. Ultrasonic sensors detect obstacles in realtime.
3. If the distance of the obstacles less than 3 meter, then Pi NoIR camera will be activited.

4. The results obtained from the ultrasonic sensor are sent for processing with the Fuzzy Logic Controlled Method at the Rasberry Pi.
5. Finally Raspberry Pi will determined the navigation system after comparing between the output of Raspberry Pi and The Rule base.
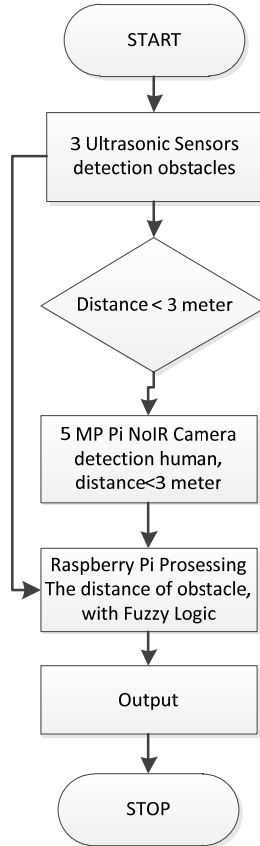

Figure 4. Flowchart Proposed System
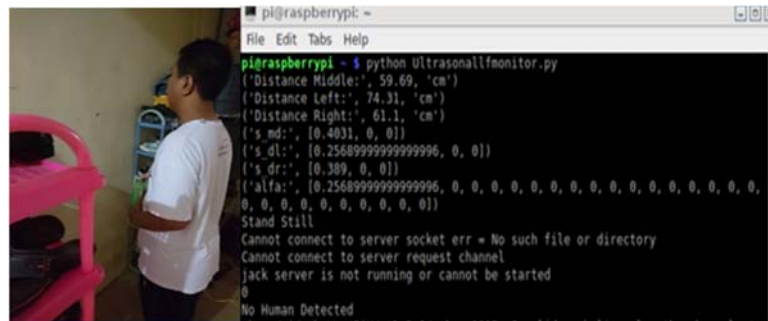
4. Result Experimental

In this study, distance detection becomes important, because the system can inform user the direction that they must through. Table 3 shows detection distance by ultrasonic Sensor as follows:

Table 3. Error Distance Detection for HC-SR04

No.	Distance Object	Measurement Distance	%error
1.	10	10.47	4.70
2.	20	19.84	0.80
3.	30	29.29	2.37
4.	40	39.59	1.03
5.	50	48.31	3.38
6.	80	77.16	3.56
7.	100	98.07	1.93
8.	150	148.85	0.77

Based on the experiment result shown in Table 3, that shows average distance error amount 2.32%.

The next test was Object Detection, can be seen in Figure 5, that is, in front, the front left and right front of the user there are obstacles. The output on the headset is information on the "Stand Still" direction. This is in accordance with the actual situation, namely the direction that should be taken is to stay in place because on the front, front left and right front of the user there is a barrier.

(a) Object Detection   (b) Simulation Program

Figure 5. (a) (b) Object Detection Test

5. Conclution

Based on the result of the experiment and data analysis that ultrasonic sensor HC-SR04 able to detection the distance within average error ±2.32%. The proposed design able to detection human, objects, and gave the navigation system effectively.

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7. Acknowledgment