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Blind Cane Using 2 Axis Servo with Fuzzy Logic Method

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Abstract: Based on data from the Ministry of Health and the Central Bureau of Statistics, it is known that the number of people with disabilities, especially the visually impaired, is 1-1.5% of the total 237 million Indonesian population, which is around 3.75 million blind people. A tool often used to accommodate them is a cane used to feel the ground if there are downgrade and obstructions in front of them. In this study, researchers developed the previous research on blind cane using a 2 axis servo. It was classified using the Fuzzy Logic programming method, which was processed using the Arduino Nano 328P microcontroller. The results of the test on respondents with visual impairments were that they feel accommodating with the tool because the cane users can easily find obstructions with the Navigation Instruction so that they can easily avoid Static obstructions (Static Objects).

Keywords: Blind cane; 2 axis servo; Fuzzy logic.

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Introduction

Blindness, according to the Great Indonesian Dictionary, is a condition where a person cannot see. Based on the Ministry of Health (2015) data, the number of people with disabilities, especially the visually impaired, is 1-1.5% of the total 237 million Indonesian population, which is around 3.75 million visually impaired people. To date, an assistive device that visually impaired people often use is a walking aid in the form of a white cane or trained dogs to help increase their safety and independence when walking (Subandi, 2010). Even though they have been assisted by walking aid, many incidents can endanger the visually impaired people, such as falling into a ditch or bumping into something when walking (Purwanto, 2010).

Based on research by Suhaeb, (2016), it is known that an electronic cane has been designed for visually impaired people with a working system of 4 ultrasonic sensors that detect obstructions in front, right, left, and below the people. The weakness of this design is that the obstacle detection navigation system is still not optimal. Based on the problem, the idea arises of finding the right solution to help visually impaired people know what objects are in front of them or what obstructions they are facing.

In contrast to the previous studies, the researcher would develop navigation using a 2 axis servo to direct the cane user to avoid obstructions in front of him. Suppose the ultrasonic sensor detects an obstacle on the right. In that case, the horizontal axis servo will direct the user's finger to the left to direct the user's steps to the left to avoid the obstacle. A sound effect will be added to the headset that will ease the cane user. The logic method that will be used is the fuzzy logic method. A fuzzy logic method is a structured and dynamic numerical estimator. This system can develop intelligence systems in an uncertain environment (Harahap, 2019). The researcher applies the fuzzy logic method to assistive devices for visually impaired people because it can produce optimal results in its implementation.

Method

The blind cane was divided into four parts. These parts have different functions. Part 1, as described in

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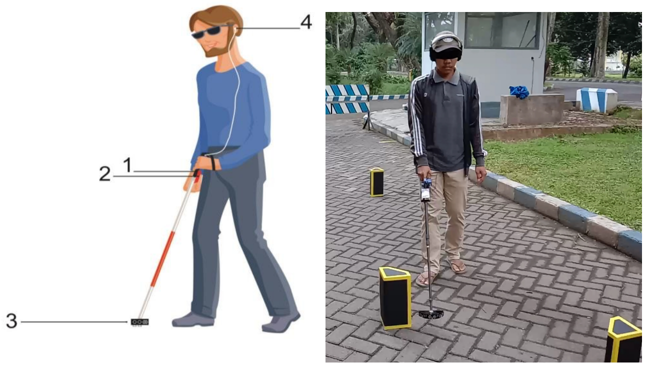
the picture, is a Vertical & Horizontal driving servo. By moving the index finger of the cane, the user wass guided to facilitate navigation. Part 2 was where the microcontroller and hardware were stored with some hardware, namely Arduino, Batteries, and DFPlayer mini. Number 3 is four Ultrasonic Sensors facing several sides: front, bottom, right, and left. Number 4 was Headphones to provide sound effects to understand better what road terrain was around. Figure 1 is the design drawing of a blind cane and its parts.



(a) (b)

Figure 1. Blind cane, a) concept, b) testing

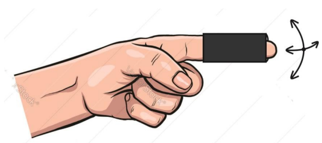


Figure 2. Servo 2 Axis Horizontal & Vertical Navigation

Figure 2 is a navigation direction function with a servo that interpreted a direction if there was an obstacle on the left side of the sensor so that the Horizontal servo would direct the index finger to the right. When there was an obstacle on the front side of the sensor, the Vertical servo would point the index finger down, which means "stop there is an obstacle in front."

One of the FIS methods used to make decision was Sugeno Fuzzy method (Athia, 2010). Fuzzy basic rules defined the relationship between membership functions and outcome membership functions. The following is a block diagram design for the blind cane.

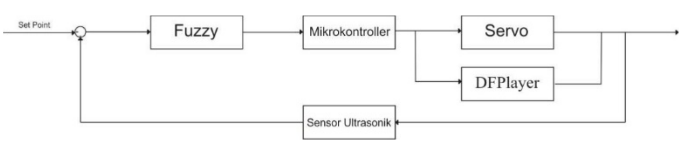


Figure 3. Block Diagram of Blind Cane

Based on Figure 3, it can be seen that the set point at the beginning of the input was in the form of distance analysis. When entering the fuzzy block diagram, there would be a classification process so that it would be processed on the microcontroller. The microcontroller would execute which program would be run from the distance classification results in the actuator in the form of 2 Horizontal and Vertical servos that navigated the cane user to direct them into the right path. It was whether there were obstructions or holes in front of the sensor. The navigation effect was a sound effect played when getting commands from the microcontroller. The ultrasonic sensor functioned as feedback which scanned the obstructions in front of the sensor.

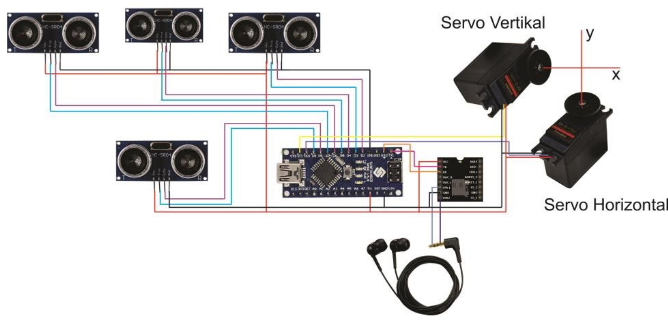


Figure 4. Wiring circuit for blind cane

Based on Figure 4, Arduino Nano as the microcontroller functioned as a data processor from 4 ultrasonic sensors that sent data in the form of distance between the sensor and obstruction located in front of the four sensors, 2 Servo functioned as an actuator when there was an obstruction, the servo moved at an angle (-200), (-100), 00, 100 and 200. The sound effects from these sensors provided information to the user through earphones available on the tool, with a power supply of 4.2 volts from 2 18650 batteries arranged in parallel.

Fuzzy logic is generally applied to problems that contain elements of uncertainty, imprecision, and so on. Mamdani, Sugeno, and Tsukamoto are several types of FIS based on the method that builds them (Zulkifli, 2017).

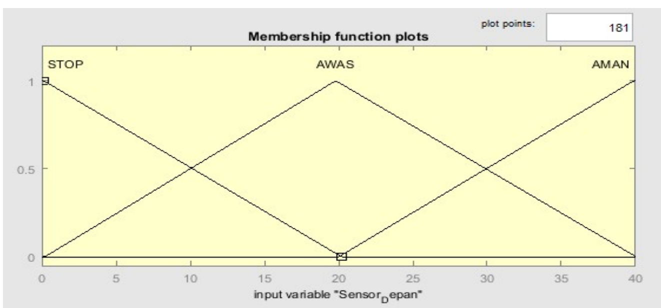


Figure 5. Front Sensor Distance Input Variable

The design of this cane, which can be seen in Figure 5, showed that the Front Sensor was divided into 3 Membership functions, namely "SAFE," which means the system was at a vulnerable distance of more than 30 cm, "CAUTION," which ranged from the obstruction distance to the sensor less than 30 cm. cm - 11 cm, and the last one was "STOP" which means a very close object with a range of less than 10 cm - 0 cm.

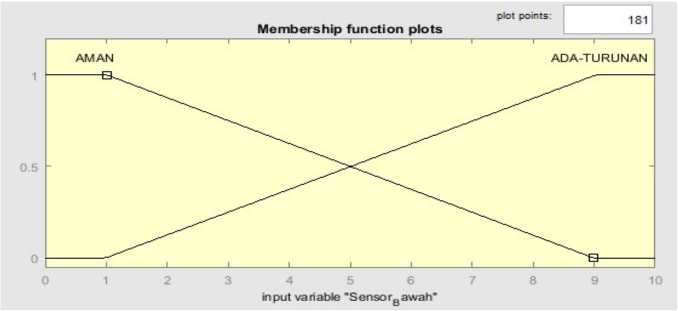


Figure 6. Input Variable Lower Sensor Distance

Figure 6 is the Input Variable from the Bottom sensor, which was divided into two membership functions; the first was "SAFE," with a range of 0 to less than 5 cm, so the sensor detected that there was no hole or downgrade on the surface, the next was the function membership of "A DOWNGRADE" which was with a range of more than 5 cm so that when the sensor detected a hole, it entered the function.

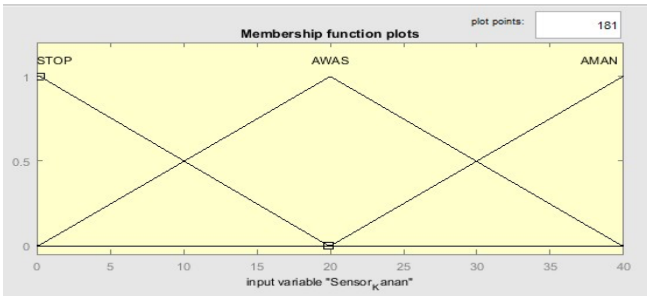


Figure 7. Variable Input Distance Sensor Right and Left

Figure 7 is a Variable from the Right and Left Sensor Inputs with three membership functions, namely the first "STOP," with a range of distance from the sensor less than 10 cm; the next was the membership function "CAUTION," which was at a range of more than 10 cm to less than was equal to 30 cm. The last membership function was "SAFE", which was at a distance of more than 30 cm, so the system was fuzzy from the three membership functions of the Right sensor.

Result and Discussion

The discussion in this study discussed the test results from several aspects, such as the results of the characteristic test of the ultrasonic sensor and percent error, the results of the angle and distance effectiveness test on the ultrasonic sensor, which tested the range of the center angle of the ultrasonic sensor, so that in its implementation it would obtain an optimal angle within the range of the sensor angle and the overall test results from various aspects, namely testing from the distance of the sensor from the obstacle, the servo output X (Horizontal) and Y (Vertical), the direction of the index finger direction from the servo, sound effect output and indicators of success or failure of all the tests.

Testing of Ultrasonic Sensor Distance Readings and percent Error

In this test, we compared the distance read on the sensor with the distance measured with a distance-measuring instrument in centimeters (cm). Thus, the difference between the two were a benchmark for the accuracy of the sensor readings. This test was assisted by using a beam measuring 10 cm high, 5 cm wide, and 4 cm long. The results of the measurement of 4 sensors with the actual distance and percent error are shown in Table 1. The error limit in the test was set at 90% accuracy. This means that if in this test, the error rate of each of these sensors exceeded 10%, it could be said that the sensor was inaccurate (Fauroq. et al., 2018). Based on the table above, it can be concluded that Sensor 1, Sensor 2, Sensor 3, and Sensor 4 the results were accurate at a distance measurement of 5 cm. Likewise, with the actual distance of 10 cm, 15cm, 20 cm, and 30 cm, all results were accurate.

Effectiveness Testing between Angle & Distance Ultrasonic Sensor

Front Sensor Test

Based on table 2, it can be concluded that the test results at a distance of 5 cm was accurate because the percent error obtained was below 10%. Then from the entire distance that had been tested, the most significant percent error was at a distance of 20 cm, with a percent error value of 9.7%, with the most significant difference value from the actual value was at an angle (-15°) of 23.5 cm.

Right Sensor Test

Based on Table 3, it was known that at a measurement distance of 10 cm and 15 cm, the highest percent error results were 10.7% and 10.6% on the right sensor. The most significant difference with the actual distance was when at a distance of 10 cm at an angle (-15 °) and 15 °. This happened because, at that angle, the obstacle object was quite far from the ultrasonic sensor trigger emitting point with signal reflection results that significantly impacted the angle of the sensor reading (Bunnan et al., 2016). This also happened when the test was distanced 15 cm at an angle (-15°) and 15°. Thus, it can be concluded that at a distance of 10 cm and 15 cm at an angle of (-15°) and 15°, respectively, it had a relatively low level of effectiveness because the percent error value in the distance and angle test had a percent error rate of 10%.

Left Sensor Test

Based on table 4, it was known that the 20 cm distance test had the most significant Error % value of 8.2%, with the difference between the results and the most considerable actual distance at an angle (-15°) of 22.86 cm, and 22.31 cm at an angle (-10°). This happened because the process of transmitting and reflecting sound with objects released by the ultrasonic sensor was slightly inaccurate. After all, the angle was large enough to affect the sensor reading (Singh, 2020). However, for the Left Sensor that had been tested, it can be concluded that the Sensor reading was Accurate because the Maximum Error percent limit was below 10%.

Table 1. Measurement Results of 4 Sensors with Actual Distance and Percent Error

Distance (cm)	Sensor 1 (cm)	Sensor 2 (cm)	Sensor 3 (cm)	Sensor 4 (cm)	Average (cm)	E%	Result
5	5.21	5.31	5.19	5.25	5.24	4.50	Accurat
10	10.12	10.23	10.10	10.32	10.19	1.80	Accurat
15	15.09	15.14	15.22	15.31	15.19	1.20	Accurat
20	20.11	20.00	20.13	20.24	20.12	0.50	Accurat
30	30.04	30.06	30.15	30.28	30.13	0.40	Accurat

Table 2. Results of the Angle and Distance Effectiveness Test from the Angle Front Sensor

Distance (cm)	(-15°) (cm)	(-10°) (cm)	0° (cm)	10° (cm)	15° (cm)	Average (cm)	E%
5	5.24	5.26	5.21	5.14	5.24	5.20	4.00%
10	10.23	10.71	10.07	10.75	10.74	10.50	4.70%
15	17.21	16.46	15.46	16.32	16.21	16.30	7.90%
20	23.50	22.16	20.00	22.07	23.02	22.15	9.70%
30	33.59	31.48	30.58	32.58	32.17	32.08	6.40%

Table 3. Results of the Angle and Distance Effectiveness Test from the Right Sensor

Distance (cm)	(-15°) (cm)	(-10°) (cm)	0° (cm)	10° (cm)	15° (cm)	Average (cm)	E%
5	5.10	5.37	5.21	5.14	5.03	5.17	3.20
10	11.60	10.53	10.63	11.33	11.91	11.20	10.70
15	17.09	16.19	15.54	17.83	17.25	16.78	10.60
20	22.78	22.48	20.20	22.83	22.14	22.086	9.40
30	32.46	32.56	30.57	31.60	31.66	31.77	5.50

Table 4. Results of the Angle and Distance Effectiveness Test from the Left Sensor

Distance (cm)	(-15°) (cm)	(-10°) (cm)	0° (cm)	10° (cm)	15° (cm)	Average (cm)	E%
5 cm	5.19	5.24	5.03	5.29	5.45	5.24	4.50%
10 cm	11.10	10.47	10.37	10.58	11.19	10.70	6.50%
15 cm	16.33c	15.47	14.91	16.84	16.21	15.90	5.60%
20 cm	22.86	22.31	20.02	22.50	21.56	21.85	8.20%
30 cm	33.82	33.16	30.11	31.94	33.31	32.46	7.50%

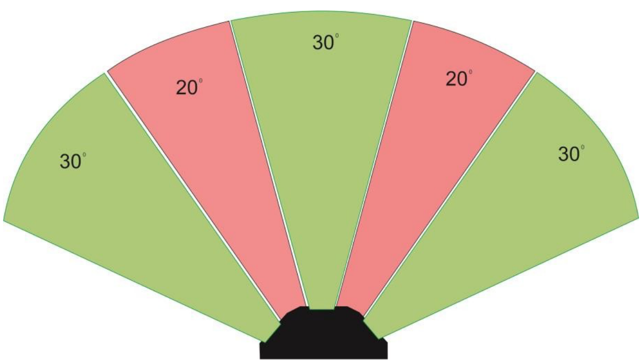


Figure 8. The Visualization of the Ultrasonic Sensor Angle Range

Bottom Sensor Fuzzy Test Detects Obstacle

Figure 10 shows the serial output of the Arduino port monitor to detect downgrades. The fuzzy system gave an output of "A DOWNGRADE" which means that when the sensor was above 5 cm above the floor surface, the Fuzzy system classified the feedback from the sensor as a floor surface transition. Front, right and left sensors detected no obstructions with the "SAFE" output.

Ultrasonic Sensor Testing with Fuzzy Logic Control

The next step was data processing by the microcontroller using fuzzy logic with the steps of fuzzification, inferent, and defuzzification steps. Then, the Ultrasonic Sensor data entered the microcontroller's process to process data from the four Ultrasonic Sensors. The goal was to determine the Servo X and Y outputs and the output of the sound effects connected to the headphones on the prototype.

Front Sensor Fuzzy Test Detects Obstacle

Based on the experimental results, when the front sensor detected an obstacle with a distance of 5cm, the Fuzzy system output can be seen as in Figure 9, the Arduino serial monitor port in which the Front Sensor result was "STOP", it means that when there was an obstacle on the Front Sensor, the system notified the user to Stop because the obstructions were detected so that the cane user could avoid the obstructions in front of him.

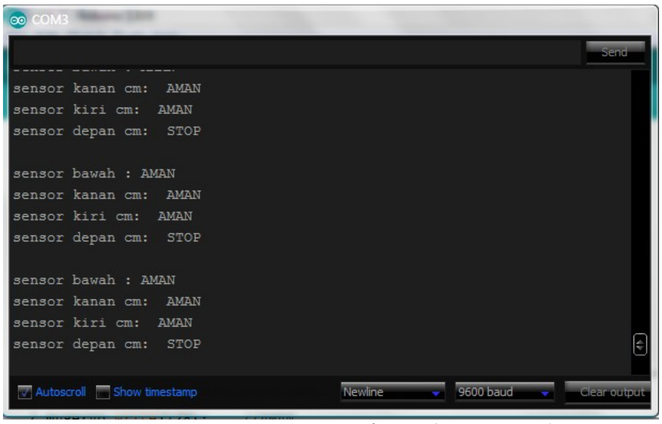


Figure 9. Fuzzy System Output from the Front Ultrasonic Sensor

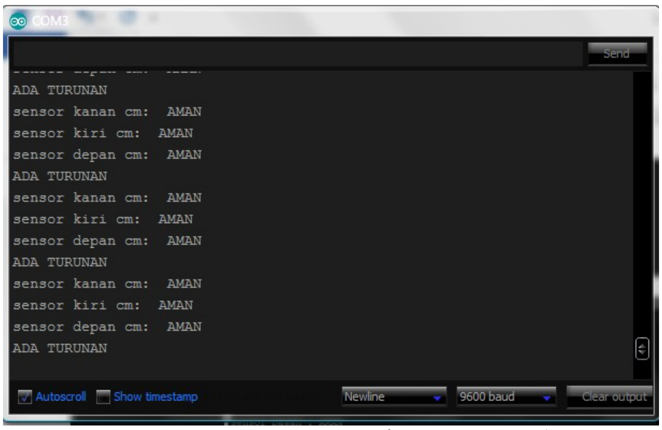


Figure 10. Fuzzy System Output from Bottom Ultrasonic Sensor

Right Sensor Fuzzy Testing Detects Obstructions

The Fuzzy system provided a "TURN LEFT" output when the right sensor detected an obstruction that the user would be directed to Turn left to avoid obstruction. When the distance between the obstruction and the right sensor was less than 10 cm, the Fuzzy system provided an output like Figure 11. While the front, left, and bottom sensors detected no obstructions with a "SAFE" output.

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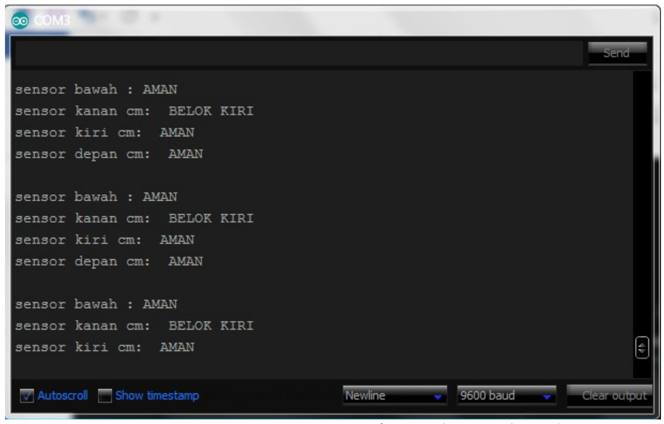

Figure 11. Fuzzy System Output from the Right Ultrasonic Sensor

Left Sensor Fuzzy Testing Detects Obstructions

Figure 12 is the output of the Serial Monitor Arduino port with the result of the left sensor detected an obstruction with the Fuzzy logic system "TURN RIGHT" output. Based on the results of the study, it was concluded that the four Fuzzy logic system tests that had been carried out, namely on the front sensor, lower sensor, right sensor, and left sensor, were successful because the input and output response of Fuzzy logic was in accordance with the goals so that the inputs and outputs processing on the microcontroller could respond according to what had been designed.

Figure 12. Fuzzy System Output from Left Ultrasonic Sensor

Overall testing

Front Sensor

The front sensor was tested three times at different distances of 5 cm, 15 cm, and 35 cm. The result of the front sensor test at a distance of 5 cm was that the cane user's index finger pointed down, with the Headphone's sound effect was "stop there is an obstruction in front". Based on the test response results at a distance of 5 cm from the Ultrasonic sensor located in the front, it was successful because of there were a sensor input, Fuzzy logic with X and Y-axis Servo Outputs, and sound effects from the microcontroller according to the design, and direction of the finger towards the bottom.

The result of the front sensor testing at a distance of 5 cm was that the user's finger pointed down slightly without sound effects. It was because at that distance, the Fuzzy logic system would only give a warning in the form of repeated servo movements with an angle of 0° and (-15°), which would warn the user that the obstruction was at a distance of less than 30 cm and no more than 10 cm. Its function was only to warn users so that they could avoid obstruction in front of them. Based on the test results of the front sensor at a distance of 15 cm, it could be claimed as successful because there were Ultrasonic Input with Fuzzy control logic produced outputs from X and Y Servos without sound effects by pointing the user's index finger down slightly to warn that the obstruction was less than 30 cm from the sensor located in front of the cane.

The test result at a distance of 35 cm was that the Fuzzy control system provided no Output response because that distance belonged to the safety limit of the system. The detected distance was more than 30 cso the X and Y axis Servos neither point to the user's finger nor the output of the sound effect provided no sound output on the Headphones. Based on the overall test results, at a distance of 5 cm, 15 cm, and 35 cm according to the design, the overall results of the inputs and outputs that had been tested were entirely in line with expectations.

Bottom Sensor

The result of the lower sensor test was obtained when testing the distance of sensor input of 5 cm with Servo X Output, which is 0°, and Servo Y 0° without sound effects heard from the headphones because at that distance, the Fuzzy control classified the sensor above the floor surface. Hence, the system classified the distance as "SAFE" without downgrade transitions. Based on the test experiments, the 5-cm-finger test was said to be successful according to what had been designed in Fuzzy logic.

Next, in testing the distance of 15 cm from the lower sensor, the Fuzzy system classified the downgrade under the sensor. The X-axis Servo Output was 0°, and the Y-axis Servo was 20° which meant it directed the user's index finger towards the top. The output of the system would provide an instruction "Beware of a downgrade" so that cane users could be careful when stepping down to transition the floor surface.

Right Sensor

The output of the sound effect was "Turn Left" which indicated an obstruction in front of the right sensor so that it directed the cane user towards the left to avoid the obstruction. A distance of 15 cm at the right sensor input would produce X servo output (-10°), and Y Servo with an angular output of 0°, which pointed the user's finger towards the left was a warning of obstruction of less than 30 cm from the sensor without sound effect output on the Headphones. The test distance of 35 cm from the right Ultrasonic sensor obtained the output of the X servo, which was an angle of 0°, and a Y servo, which was an angle of 0° without sound effects. It was because in this distance, the Fuzzy control system classified it as "SAFE" limits.

Left Sensor

The overall test results of the left sensor with the first test were at a distance of 5 cm from the sensor as input from the Fuzzy control system with results on X Servo with an angle of 20° and Y Servo of 0° by pointing the user's finger towards the right, accompanied by the output of the sound effect "Turn Right" to avoid obstruction on the left detected by the sensor. The test result of the sensor input at a distance of 15 cm with the result of X Servo Output 10° and Y Servo 0° with the direction of the finger crooked to the right, without any sound effects. Thus, the cane user would get a warning from the servo, which was crooked to the right. The last test was at a Sensor Distance of 35 cm with an X Servo output of 0° and Y Servo of 0° without sound effects because if the distance was above 30 cm, it was classified by the system within the "SAFE" limit in the Fuzzy control system.

Based on the results of all tests carried out from the front sensor, the lower sensor, the right sensor, and the left sensor assessed from the aspect of input and output were entirely declared successful.

Overall Testing by Respondents

In this study, respondents simulated visually impaired people in general. Respondents were tested with an obstruction object, downgrade transitions, and uneven roads. Therefore, the results obtained would be a reference in the development of this Blind Cane. The following are the results of the overall testing of the respondents.

Based on table 5, it can be seen that the results of the overall test of the blind cane aspects of 4 respondents were successful. Respondent 1 and respondent 2 could go through any surface and three obstructions with results expected by the researcher; in contrast to respondent 1 and respondent 2, respondent 3 experienced failures in passing the flat block paving at the third obstruction. This was because when passing through the flat block paving on the third obstruction, respondent 3 touched the simulation object. Based on the presentation of respondent 3, the reason respondent 3 touched the obstacle was that respondents were too careful in their steps, so they were inconsistent in determining the direction of walking. This caused part of the Respondent's left foot to hit Object 3.

Table 5. Overall Test Results by Respondents

Respondents	Types of Surfaces	Obstructions 1	2	3	Result
1	Flat Block Paving	V	V	V	Succesful
	Flat Ceramics Floor	V	V	V	Succesful
	Uneven Road Surface with Downgrade	V	V	V	Succesful
2	Flat Block Paving	V	V	V	Succesful
	Flat Ceramics Floor	V	V	V	Succesful
	Uneven Road Surface with Downgrade	V	V	V	Succesful
3	Flat Block Paving	V	V	X	Failed
	Flat Ceramics Floor	V	V	V	Succesful
	Uneven Road Surface with Downgrade	V	V	V	Succesful
4	Flat Block Paving	X	V	V	Failed
	Flat Ceramics Floor	X	V	V	Failed
	Flat Block Paving	V	V	V	Succesful

Based on the above presentation, it can be concluded that of the 12 trials that 4 respondents had carried out, a total of 36 obstructions resulted in 3 failures because the respondent hit one of the three obstructions, and 33 times managed to pass the obstructions, with a ratio of 3:36, then for the effectiveness level, which is 91.60% or with an Error percent of 8.30%. Respondent 4 experienced failure 2 times, namely in the type of flat block paving surface obstructions 1 and the type of flat ceramics floor surface obstacle 1. Respondents nudged the first obstruction, and were able to pass obstacles 2 and 3 as well as the existing downgrade transitions, due to limited space and place that resulted in respondents being less flexible in conducting the trial.

Conclusion

Based on the results of several tests in this study, it can be concluded that the product of this study is considered capable of being a reliable tool for people with disabilities, particularly the visually impaired one. This is evidenced by the results of testing respondents with visual impairments, which is feeling greatly helped by the tool because they can easily find obstructions with navigation instructions to avoid static obstructions (stationary objects). This blind cane has a sensor accuracy rate, sensor angle effectiveness, and overall testing by respondents with a success rate of 91.60% and error percent of 8.30%. The level of effectiveness of the sensor is determined by the angle of reflection from the obstacle in front of the sensor; the smaller the reflection angle from the midpoint of the sensor, the better the sensor reading result is at a range of 300 from each sensor.

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