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A Movement Guidance System for the Blind Using a Fuzzy Logic Controller

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ABSTRACT

Safe and independent mobility is significant for blind persons due to the diverse nature of the surrounding environment. The fuzzy logic system has features that make it a suitable tool to address this problem and provide safe motor guidance through its fuzzy steering decisions, to avoid collisions with obstacles during mobility, this study aims to implement a fuzzy logic controller as a system to help blind persons' for movement guidance and prevent collisions with obstacles during movement. The system consists of three ultrasonic sensors as a guide to movement, mounted on a stick to guide the blind person. This system can provide a solution to help these people during their movement without the help of others, the system has been tested several times to ensure its accuracy and effectiveness, and the experimental results showed that, through result in the movement guidance and the fuzzy rules that were created to obstacles collision avoidance, the system can assist the person by guiding them as they navigate their environment and avoid collisions with obstacles.

نظام توجيه حركي للمكفوفين باستخدام متحكم المنطق الضبابي

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الكلمات المفتاحية:
الأشخاص المكفوفين
متحكم المنطق الضبابي(FLC)
التوجيه الحركي
تجنب الاصطدام
التنقل المستقل الأمن

الملخص

يمثل التنقل الآمن والمستقل أهمية كبيرة للأفراد المكفوفين بسبب الطبيعة المتنوعة للبيئة المحيطة. يتمتع نظام المنطق الضبابي بميزات تجعله أداة مناسبة لمعالجة هذه المشكلة وتوفير التوجيه الحركي الآمن من خلال قراراته التوجيهية الضبابية، لتجنب الاصطدام بالعقبات أثناء الحركة، تهدف هذه الدراسة إلى تطبيق وحدة تحكم المنطق الضبابي كنظام لمساعدة المكفوفين لتجنب الأفراد الاصطدام بالعقبات أثناء الحركة. ويتكون النظام من ثلاثة أجهزة استشعار بالموجات فوق الصوتية كدليل للحركة، مثبتة على عصا لتوجيه الشخص الكفيف. ويمكن من خلال هذا النظام تقديم حل لمساعدة هؤلاء الأشخاص أثناء حركتهم دون مساعدة الآخرين، تم اختبار النظام عدة مرات للتأكد من دقته وفعاليته، حيث أظهرت النتائج التجريبية من خلال نتيجة التوجيه الحركي والقواعد الغامضة التي تم إنشاؤها لتجنب الاصطدام بالعقبات، النظام قادرا على مساعدة الشخص عن طريق التوجيه أثناء التنقل في بيئته وتجنب الاصطدام بالعقبات.

1.Introduction:

Persons blind face many difficulties when performing most of the activities humans do in their lives, such as detecting fixed or moving objects and navigating the environments around them safely. These activities are considered very difficult and may also be dangerous for blind persons, especially if the environment is unknown, consequently, blind persons use the same path of navigation every time.

Many scientists have published a lot of research that helps them live their lives easily and move around safely. we come to the Braille method of reading, one of the greatest inventions known to man to serve the blind. He invented a system of writing and reading by passing the fingers over prominent letters, that is, the images in it have tangible features. with this invention, he opened wide horizons for blind persons all over the world and in various languages [1],

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persons who are blind or visually handicapped often use guide dogs or white canes to help them find their way and avoid obstacles. They cannot judge the risk they pose or identify impediments at eye level though. Although they are expensive and need a lot of training, guide dogs provide useful aid with navigating. In addition, there are many problems that scientists have faced in the phenomenon of treating the blind and finding appropriate methods that rely on artificial intelligence algorithms for years, and methods for finding solutions for people with visual impairment have been presented in the scientific is and a source of challenge for scientists, However, none of these solutions have been implemented that would help create an actual system to serve people who are blind and One of the most important motivations for engaging in this study is to present a new method for movement guidance avoiding obstacles for a blind person based on a FLC.

The organization of this paper is the following: Section II related works and presents a study and assistive technologies for blind people. The proposed system is described in Section III. Implementation and experimental setup results are presented in Section IV. Section V Conclusion of the paper.

2. Related Works

Many scientists have published research and dissertations that included many solutions, but none of these solutions were implemented, many systems were presented that faced many problems in implementation, such as the system stick the electronic that identifies the obstacles in front of the infected person gives a warning when there are obstacles in front of the infected person, it faced many problems with the infected people and caused many accidents that proved the weakness of the effectiveness of the system and its operation. Hence, scientists began to develop methods and systems that rely on artificial intelligence, including fuzzy logic controllers. A new obstacle detection algorithm based on image depth information and fuzzy logic is proposed in [2], using fuzzy logic, it was able to provide accurate information to help the blind user, as for [3], the system consists of ultrasonic sensors, a PIR motion sensor, an accelerometer, a smartphone application, a microcontroller, and a data transmission device. The microcontroller transmits data to the user's smartphone via a Bluetooth module; the smartphone application generates audible instructions to properly guide the user. The study [4] also proposed planning the optimal path for a mobile robot using an optimization algorithm WDO with a type-I fuzzy controller, and the simulation was performed on a Khepera-III robot It is a robot inspired by the Earth's atmosphere; Fuzzy-WDO algorithm was used to optimize and adjust the parameter outputs, the ultrasonic sensor reads obstacles from 20 cm to 4 approximately meters.

Obstacle identification and avoidance is also an important and widespread topic in the field of collision avoidance systems. Obstacle avoidance techniques can be divided into three categories based on the type of sensors used: ultrasonic sensor-based [5], laser scanner-based [6], and camera-based [7].

Methods using ultrasonic sensors measure the distance to the obstacle and compare the result to a pre-determined threshold to determine how much time has passed. However, you may experience signal problems or interference in indoor areas when using them, especially when using ultrasonic radar or sensor arrays, and they may not provide accurate directional information; but it Relevance in dark conditions and nearby things from blind person.

Because laser scanners have high resolution, they are frequently used in mobile automation systems such as self-driving cars. Unfortunately, its high cost, weight, and high energy consumption make it unsuitable for wearable mobility systems, and obstacle identification and avoidance have been extensively studied [8] [9].

RGB-D cameras are also very popular due to their low cost, small size, and ability to provide detailed information. It combines range, depth, and color information. Study [10], one RGB-D camera-based solution uses both range and color information to scale floor segmentation and detect detailed obstacles.

Therefore, to avoid collisions, there are three main methods of guiding people who are blind or visually impaired: tactile, auditory, and visual. Vibrators are commonly used in haptic feedback systems on belts [11], helmets [12], and backpacks [13], and acoustic feedback systems also take advantage of acoustic patterns, semantic speech, varying sound intensity, or target auditory cues Spatially. in [14], the processed RGB image is translated directly into audio patterns, allowing blind people to perceive their environment. the depth image is converted into semantic speech to convey information about obstacles. in [15], the depth image is converted to different acoustic intensities to represent barriers at various distances. the depth image is translated into spatially defined auditory signals to convey three-dimensional information about the environment. However, the interpretation of these audio signals in crowded or complex situations can be incorrect due to loud noise.

Visual feedback systems are ideal for people with low vision because they provide more comprehensive information than tactile or audio feedback systems. The distance of obstacles is set to the brightness on the LED (light emitting diode) display as a visual magnification tool to help users detect obstacles. However, the low resolution of the LED display limits its ability to display simple obstacles [16]. To address the shortcomings of these systems, this proposed study presents a unique obstacle avoidance algorithm based on multi-sensor fusion. This method uses sensors and ultrasound to calculate the most traversable path. The transient output direction is then converted into three forms of auditory signals to assist people who are blind.

However, none of these studies provide a complete solution that can help blind persons in all aspects of their lives. And therefore; the goal of this work is to design an effective system that significantly improves people's lives, blind persons. This system can overcome the limitations of previous systems by providing movement guidance in their environment.

3. Proposed Work

The proposed system supports blind persons by providing a guidance system that helps them move and also includes ultrasonic sensors embedded in a device that can be easily carried, this auxiliary system relies on simulation and discrimination of several different levels of any variable during making decision, and this is provided by a FLC. the proposed system consists of three ultrasonic sensors, an Arduino Uno board, and a small breadboard mounted on a Stick to guide the blind persons. to provide an effective, independent, and economical optical device that aims to simulate the learning mechanism through human experience, the system can learn to perform a task by guiding blind persons. This smart device provides future horizons for creating autonomous systems. As shown in Figure 1 the Smart Sticks for the proposed system, have been designed with a SolidWorks program, to give a brief idea of the proposed system.

Figure 1: Proposed System Model.

3.1 Hardware Components for The Proposed System

For the components proposed system, we need three Ultrasonic sensors, a breadboard, an Arduino UNO board, and connecting wires M/M and M/F will be connected and placed in a box attached to a stick, as shown in Figure 2 hardware components for the proposed system.

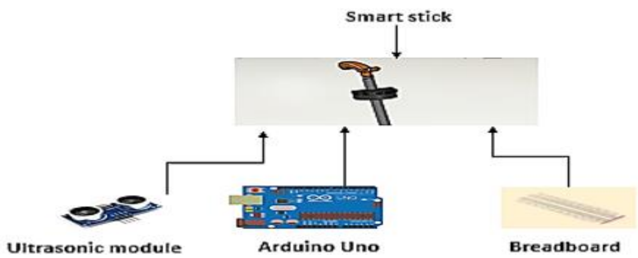

Figure 2: Hardware Components for The Proposed System.

3.2 Software Methodology For Proposed System

The proposed system will be built on the Windows 10 Pro operating system, 64bit, and a graphics processor NVIDIA Quadra M2000m, Intel core i7-6820HQ CPU@2.70 GHz 2.71 Using the MATLAB R2022b programming language.

A. Object Detection and Distance Measurement Using Ultrasonic Sensors

Three Ultrasonic sensors as shown in Figure 3 are used for object detection and distance measurement. the proposed study uses ultrasonic type HC-SR04 these sensors detect the amount of time it takes for ultrasonic waves to return after colliding with an item. the system can identify obstacles in the blind person's path and provide the necessary movement instructions by evaluating the sensor data, the user can reliably identify obstacles that are close to them with the help of the ultrasonic sensors. and it is suitable for nighttime, an ultrasonic sensor uses high-frequency vibrations to identify every object that gets in the user's path. The object reflects the Ultrasonic waves, allowing the ultrasonic sensor to detect them. The distance between the sensor and the object can be determined by timing the interval between sending and receiving sound waves [20] [21] [22]. The largest detection range is 4 meters. However, the maximum allowed ultrasound is 6 meters. Since the person only needs to avoid obstacles, the upper obstacles are identified up to a height of 1.2 meters in the air. Figure 3 illustrates the Working of the ultrasonic sensors.

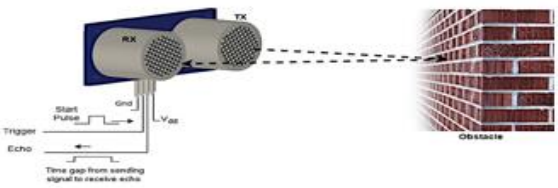

Figure 3: Working of the Ultrasonic Sensor [22].

The three Ultrasonic motion sensors precisely detect the angle at which an impediment is located. they are angled at 45, 90, and 135 degrees. the system can accurately locate barriers and provide user guidance based on this information when combined with the distance measurement. Figure 4 illustrates hardware components connect for Smart Stick, she was connected as in [22] [23].

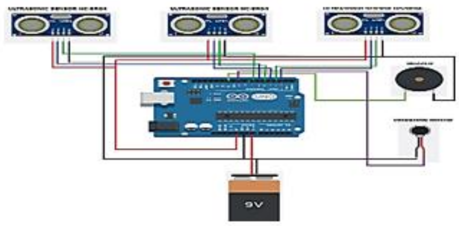

Figure 4: Connected Hardware Components for Smart Stick [23].

These ingredients are placed inside a small box and attached to a stick, as shown in Figure 5.

Figure 5: Smart Stick with three Ultrasonic Sensors.

B. Fuzzy Logic Controller

The current study uses a fuzzy controller for decision-making, which is a type of logic controller for Fuzzy logic (FL) that is used to control processes, as shown in Figure 6 the architecture FLC, FL is a way to make machines more intelligent or closer to human thinking to recognize and decide like a human, as advanced control in artificial intelligence depends on intelligent technologies called smart controllers, including the FLC, which derived its idea from the theory of fuzzy sets that Zadeh presented in 1995, FL is the broad sense is a logical system based on a generalization of traditional two-valued logic, which uses variables with real values (0, 1) and knowledge is interpreted as a set of vague constraints on a set of variables, this is for inference in the circumstances uncertain [17].

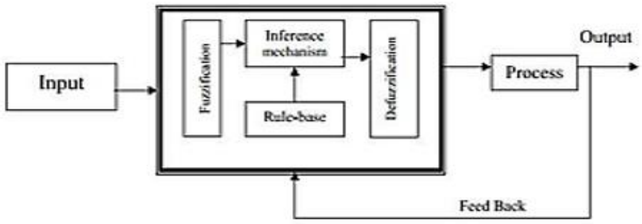

Figure 6: Architecture Fuzzy Logic Controller [18].

C. Fuzzy Logic Controller for Movement Guidance

The movement guidance system incorporates an FLC to make decisions regarding the blind person's movement based on the inputs from the ultrasonic sensors. the FLC takes into account factors such as the distance to detected objects, the speed, and the direction of movement. it uses a set of fuzzy rules to determine the appropriate movement instructions, such as stopping, turning, or adjusting speed, to avoid obstacles and ensure safe navigation. in this study, the FLC is designed for movement guidance as in [19].

The fuzzy decision-making controller for the proposed study is made up of five steps:

- **Input and output:** There are three inputs for obstacle detection depending on the person's situation Forward Obstacle Detection (FOD), Left Obstacle Detection (LOD), and Right Obstacle Detection (ROD) with distance measurement, the two outputs are left velocity (Left Walk Velocity - LWV) and right velocity (Right Walk Velocity- RWV). Thus the FLC is a three inputs and two outputs system. In this study, MATLAB’s Fuzzy Logic Toolbox was used to design the FLC, MATLAB’s Fuzzy Logic Toolbox contains functions, graphical user interfaces (GUI), and data structures that allow the user to quickly design test, simulate, and modify a fuzzy inference system, as for the linguistic variables used the three inputs are the same: near, middle and far, the linguistic variables for the directors are: slow, medium and fast. As it can be reversed or Stopped. In this study, the Mamdani fuzzy inference system is used.
- **Fuzzification:** Converts controller inputs into information that the inference mechanism can be easily used to activate and apply rules, as the membership function is expressed in a Fuzzy set with degrees of truth a continuum of values ranging from 0 to 1, The Triangle Function was used as the membership function.
- **Rule base:** A set of IF-Then rules that contains a fuzzy logic quantification of the expert’s linguistic description of how to achieve good control. FLC rules are: (number of memberships ^ number of entries), thus; the number of fuzzy rules is 3^3 = 27 rules.
- **Defuzzification:** This converts the conclusions of the interface mechanism into actual inputs for the process. In the study proposed, for secure routing, the defuzzification of the output variable is done by the gravity method
- **Output and Decision-Making:** The results of LWV and RWV are displayed, and the decision-making process and corresponding actions based on the LWV and RWV values are commented out in the code software.

Figure 7 illustrates the input and output interface for the proposed FLC system, Figures 8-a to 8-e illustrate the input and output for the FLC proposed system, and Figure 9 illustrates if-then for the proposed FLC system.

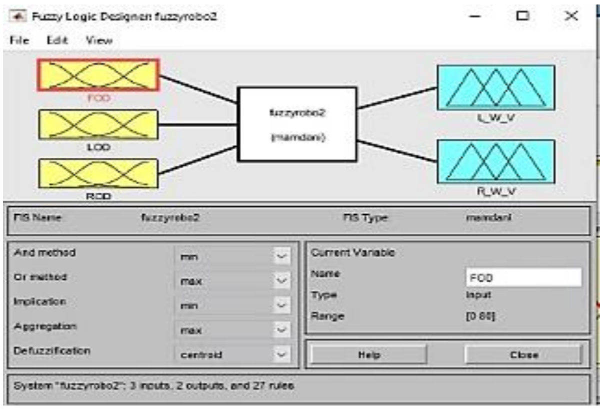

Figure 7: Interface Input And Output For FLC.

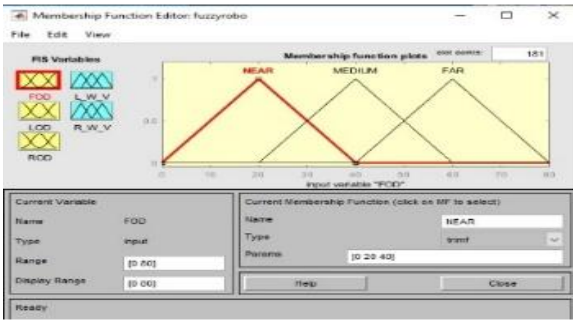

Figure 8-a: Input FOD.

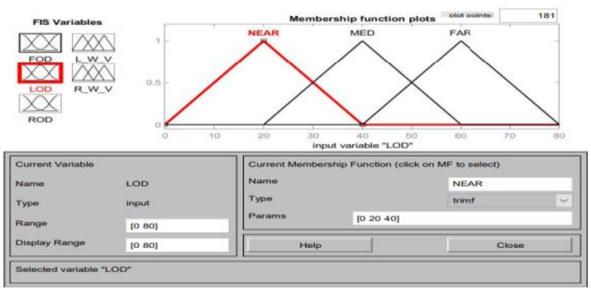

Figure 8-b: Input LOD.

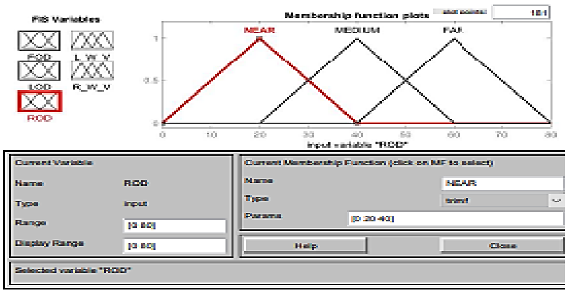

Figure 8-c: Input ROD.

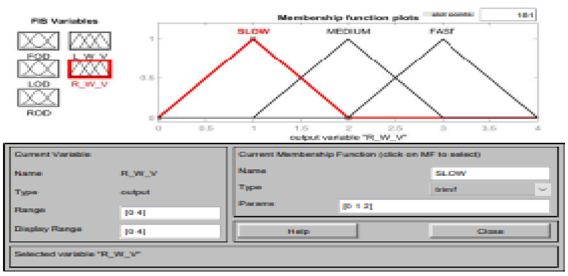

Figure 8-d: Output RWV.

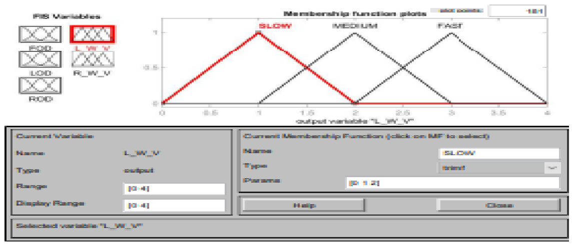

Figure 8-e: Output LWV.

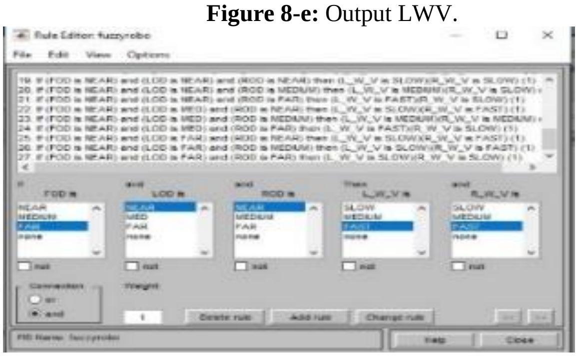

Figure 9: IF-Then for FLC.

D. Movement Guidance by Ultrasonic Sensors And Fuzzy Logic Controller for Obstacle Avoidance Collision

Distance crisp value between a person and surrounding objects is measured by an ultrasonic sensor circuit for distance measurement which is used to build the fuzzy membership function. The sensors' acquired information shows that obstacles exist near the person. When a person is close to an obstacle, it must change its velocity and steering angle to avoid the obstacle.

Fuzzy systems can handle uncertain and imprecise information acquired from sensors using fuzzy rules [18]. Figure 10 illustrates the structure of steering behavior for obstacle avoidance using an FLC.

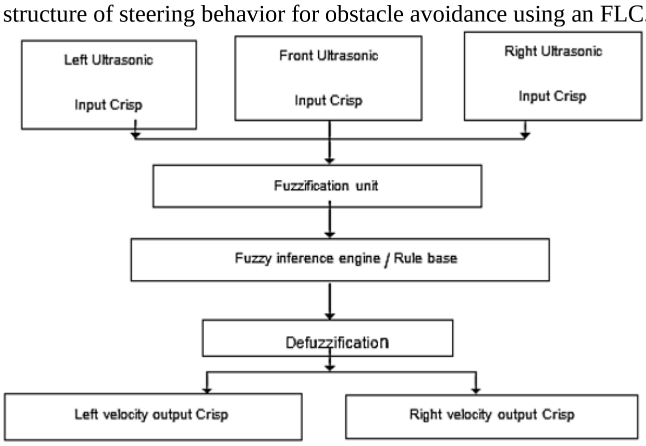

Figure 10: Structure of Steering Behavior for Obstacle Avoidance Using a Fuzzy Logic Controller [18].

The proposed study for the FLC experiment, determined are 3 inputs with 27 membership functions., and membership functions for two output variables left and right walk velocity. Whereas a model FLC has been designed to guide the movement and avoidance of collision as in [19], the parameters of the proposed study differ from them, Whereas The “If-Then” fuzzy control rules are being designed using the knowledge base as described in [19] fuzzy control rules for collision avoidance.

4. Experiment And Analyze The Results

The system was designed in the form of a Smart Stick, the next stage involved trying out the system using a sensor, it was tested on a recorded video to evaluate its effectiveness and efficiency, and the study was based on detecting obstacles using an ultrasonic sensor. we first need to detect obstacles using the sensors, then determine the location of the obstacle and distance measurement. Then the movement is guided through the FLC. This is achieved using sensor information processed by an FLC, and the system provides help to the person, through instructive instructions that are commented out in the code software.

Figure 11 shows the result of obstacle detection and distance measurement using ultrasonic sensors with movement guidance using FLC at the system testing on recorded video. Figure 12 illustrates the rules of the components FLC system for the proposed study, and Figure 13(a, b) illustrates the surface viewer for the output FLC for the proposed study.

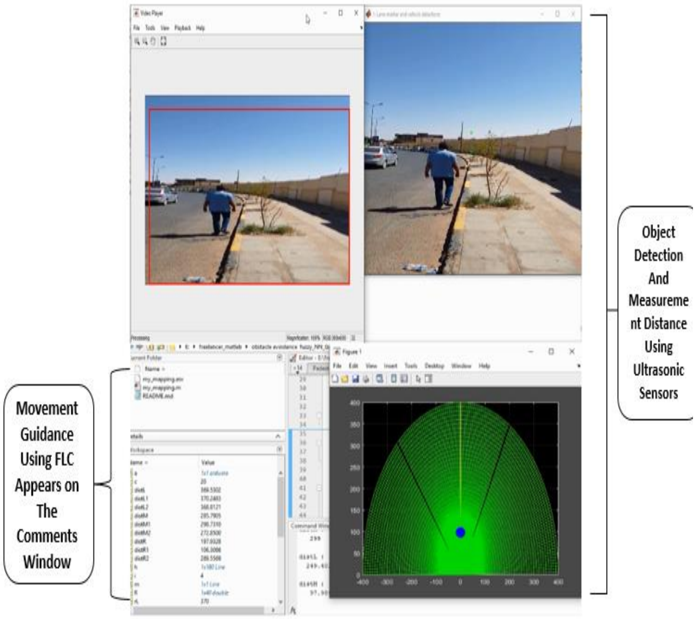

Figure 11: The Result of the Obstacle Detection and Measurement Guidance using Ultrasonic Sensors with Direct Movement Using FLC.

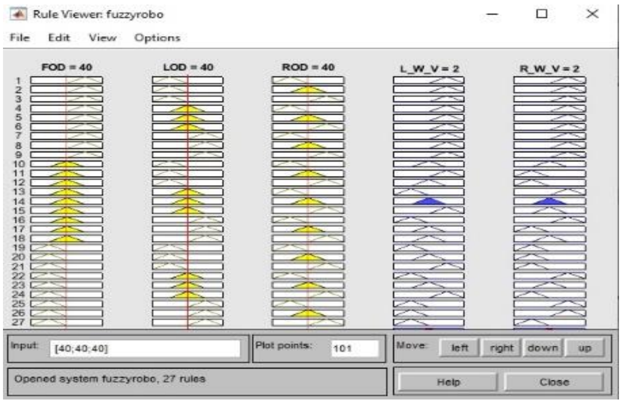

Figure 12: Rules Components FLC.

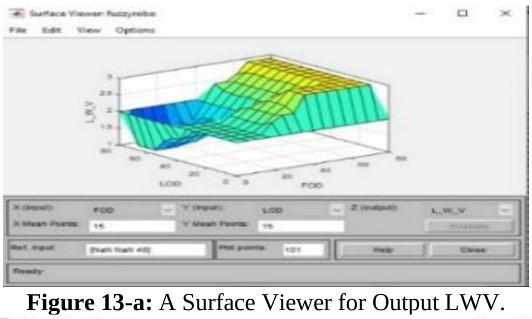

Figure 13-a: A Surface Viewer for Output LWV.

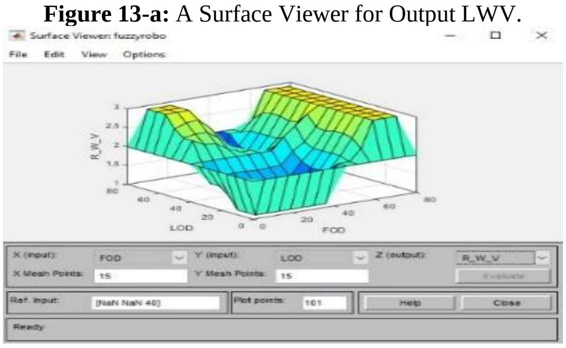

Figure 13-b: A Surface Viewer for Output RWV.

Finally; this proposed system was suggested in the study [24], it relies on a camera to detect obstacles, measure distance for a range of 9 meters, and an FLC for guidance, but the proposed study relies on ultrasonic sensors to detect obstacles and measure distance for range of 6 meters, then use the FLC to make guidance decisions to reach the intended destination without colliding with obstacles.

5. Conclusion

In this system, the physical and software aspects were implemented using MATLAB, which provides a system that can assist blind persons and provide them with motor guidance. This new electronic mobility tool facilitates the movement of blind people indoors and outdoors using sensor-based methods. The proposed system Movement guidance enables obstacle avoidance, the user can navigate his path, avoid detected obstacles, and detect them to a maximum distance of 6 meters using sensors. The system was tested several times on recorded video clips to ensure its accuracy and effectiveness. the proposed system shows outstanding performance and accuracy through experimental results to help blind persons.

6. Recommendations

- Genetic algorithm can be used to optimize fuzzy logic controller rules.

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