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FUZZY LOGIC-BASED SECURITY SYSTEM FOR REMOTE OUTDOOR CABINETS

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Abstract

Ensuring the security of cabinets located in areas far from physical access is of great importance. In such locations, various sensors are used to enhance the safety of these cabinets. These sensors monitor the surroundings of the cabinets and provide the necessary data to improve security. Fuzzy logic is employed to process this data effectively. With the advancement of technology, the importance of using fuzzy logic has significantly increased. In this study, a security system application for outdoor cabinets is designed using fuzzy logic. The primary goal of the study is to ensure the safety of cabinets in areas that are distant from human access. The details of this system are thoroughly explained in the following sections.

Keywords: Fuzzy Logic; Outdoor Cabinets; Security System; MATLAB; Fuzzy Logic Toolbox; Sensor

1. Introduction

Fuzzy logic enables the definition of variables and rules in a clear and flexible manner during modelling, though without requiring certainty. This method is particularly utilized in control engineering, especially in systems where traditional mathematical models are difficult to establish, or where known methods do not provide sufficient efficiency [1]. The advantages offered by fuzzy logic are as follows [2]:

- It closely aligns with human thinking processes and methods.
- Its application does not necessarily require a mathematical model.
- The simplicity of the software allows for the system to be established more economically.
- The use of membership degrees makes this technique more flexible than other control methods.
- It allows for the use of information that does not yield a definite outcome.
- It enables the modelling of nonlinear functions.
- A fuzzy logic-based model can be easily designed using only the experiences of experts.
- It is compatible with traditional control techniques [5].

Fuzzy logic is a mathematical system developed to handle uncertainties and imprecise information. Unlike traditional binary logic, this system allows for a more natural way of modeling uncertainties and vagueness present in the real world. The fundamental concepts of fuzzy logic include fuzzy sets, membership functions, if-then rules, fuzzification, inference, and defuzzification [3]. After deciding to design a fuzzy system, the first thing to do is to obtain "if-then" fuzzy rules. These rules are made with the help of experts. The fuzzy control chart is shown in Figure 1 below[4].

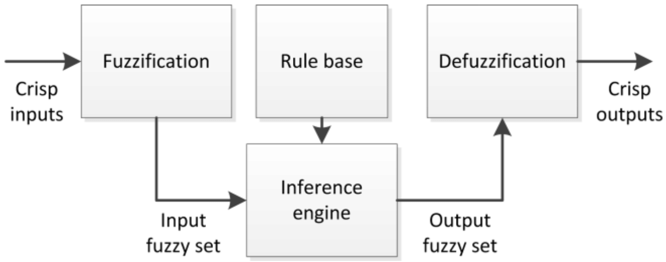

Fig. 1. Block Diagram of Fuzzy Logic

In the creation of the rule base; "Mamdani" method was used as fuzzy inference system. The Mamdani method is a system that transforms membership functions into fuzzy sets [10]. In the Mamdani system, the output of each rule is the element of the fuzzy set [11]. Outputs are obtained after the data taken as input are fuzzificated and evaluated in the database created by the expert[6]. In our study, these outputs were obtained using MATLAB application. Outdoor cabinets are used to store many electronic equipment, from battery packs to telecom equipment [7]. Currently, most outdoor cabins are installed on roadsides where environmental conditions are sometimes extremely harsh [8]. The safety of cabinets in places where human access is not easy is important. With this study, the security of outdoor cabinets has been tried to be increased. Although these cabinets are generally protected with locks, in remote areas, additional alert systems may be necessary to detect unauthorized access or potential damage [9].

With this study, it is aimed to increase the security of outdoor cabinets with a security system designed with the help of fuzzy logic. It is desired to design a security system that converts the data received from the sensors into an output with fuzzy logic for these cabinets located in places far from people.

2. Application

2.1. General Structure of the System

In this part of the study, the input values required for the control of the cabinet security system and the determination of the output values that will occur because of processing these values are shown [4]. In this study, we will examine the design of an expert system, which is controlled by fuzzy logic controllers with its general boundaries, makes the necessary controls for a safe cabin security system and can produce results accordingly. First, important, and relevant input and output values are determined. Then, the subset ranges are explained, and the shape and positions of the fuzzy subsets are determined. Then, fuzzy "if-then" rules are determined, and calculations are made. Here, we measure the force applied to the door and the smoke density in the cabin with the help of sensors we have placed at certain points on the door. In line with the values we have obtained, a possible door forcing, assault, etc. It is aimed to determine the danger by using fuzzy logic, with the warnings to be given to the environment with sound and light warnings and the warnings to be conveyed to the relevant units. In our study, a structure was considered to give warning from inside the cabin. According to the data to be obtained from the sensors, an alarm system will be used that will give loud noise and high flux light to the environment when necessary. By placing this system inside the cabin, it will give out sound and light through the spaces on the cabin and warn a living thing that may harm the cabin. This alarm system is shown in Figure-2.

Fig. 2. Outdoor Cabinet and Alarm System

2.2. Determining Input and Output Values

To prevent dangers that may occur because of violence or a fire that may occur in the cabinet, a system that gives an audible and visual alarm to the environment and sends the necessary warnings to the relevant units is controlled. In this direction, the values taken from the sensors placed in the cabinet were determined as input values, and the warning system level and Sound-Light alarm level were determined as output values.

Smoke(S) and Force(F) were determined as input parameters. The clusters of these values are shown in Figure 3.

S = { ZS, LS, MS, HS } (Zero Smoke, Low Smoke, Mid-Level Smoke, High Smoke)

F = { ZF, LF, MF, HF, UF } (Zero Smoke, Low Smoke, Mid-Level Force, High Force, Ultra Force)

Fig. 3. Input Values

The output parameters were determined as Warning System (W) and Light-Sound (VS). The clusters of these values are shown in Figure 4.

W = { NW, LW, MW, HW, UW } (No Warning, Low Warning, Mid-Level Warning, High Warning)

VS = { ZVS, LVS, HVS } (Zero Voice-Light, Low Voice-Light, High Voice-Light)

Fig. 4. Output Values

2.3. Creating the Fuzzy Rule Table

In this section, rules are determined by evaluating all the variables and possible differences. These rules have been designed under the conditions that may occur according to the values we have determined. The input to the system is defined in the "if-then" structure to be analysed on the basis of fuzzy logic, and the output data is processed. The rule table we created as a result of these data is shown in Figure 5.

		F				
		ZF	LF	MF	HF	UF
S	ZS	NW ZVS	LW LVS	MW LVS	HW HVS	HW HVS
	LS	LW LVS	LW LVS	MW LVS	HW HVS	HW HVS
	MS	MW LVS	MW LVS	HW HVS	HW HVS	HW HVS
	HS	HW HVS	HW HVS	HW HVS	HW HVS	HW HVS

Fig. 5. Rule Table

2.4. MATLAB Application

In this section, fuzzy logic inference of the system is made using the Fuzzy Logic Designer plug-in in MATLAB application in line with the rules we have determined in the previous sections. While making this design, the Mamdani method was chosen. The design prepared on MATLAB is shown in Figure 6.

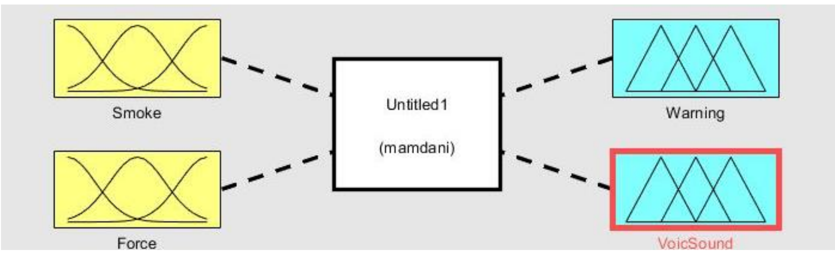

Fig. 6. Fuzzy Logic Design

After the rule table determined according to the inputs and outputs, we used in the design is prepared in the “if-then” structure. Membership Function Editor is used to determine membership functions on the application. With this editor, each input and output parameter is shown in graphically determined values. The graphs of the membership functions of the input and output parameters plotted on the application are shown in Figure 7, Figure 8, Figure 9 and Figure 10.

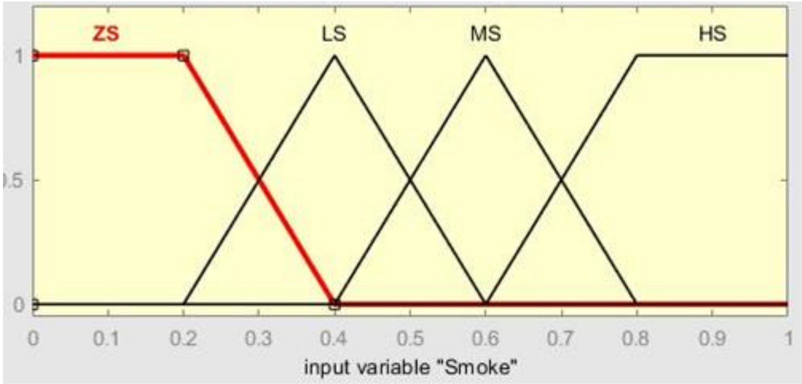

Fig.7. Membership Function Graph of Smoke Input

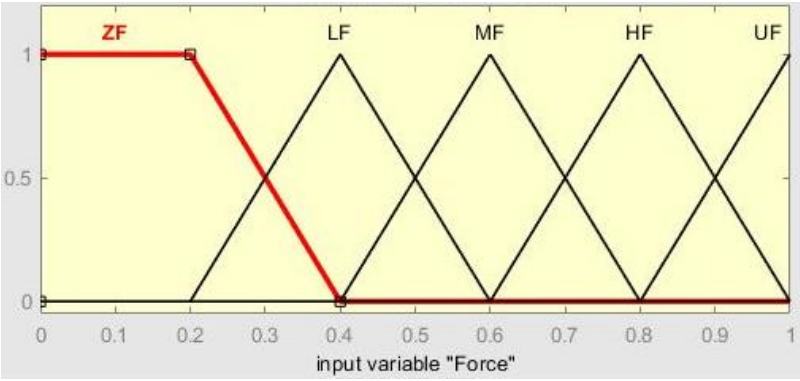

Fig. 8. Membership Function Graph of Force Input

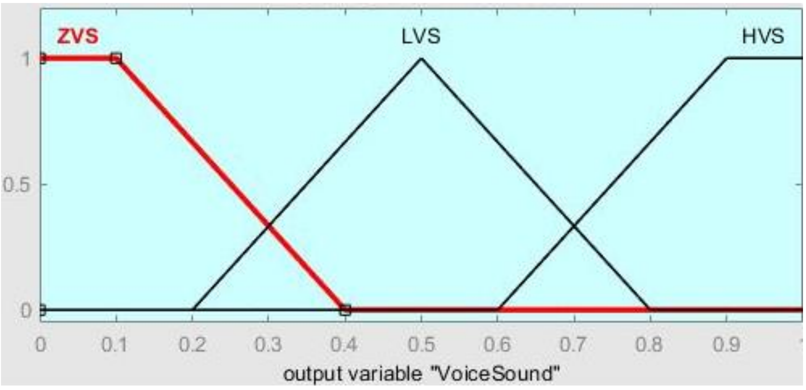

Fig. 9. Membership Function Graph of VoiceSound Output

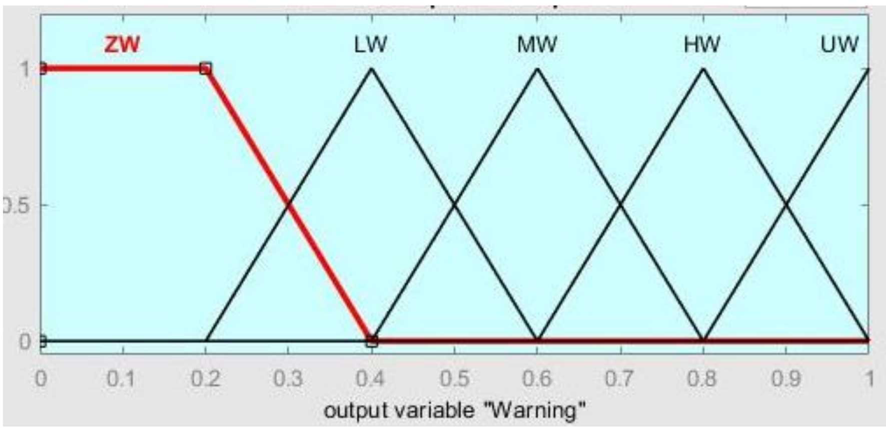

Fig. 10. Membership Function Graph of Warning Output

After the membership functions graphics were determined, results were prepared on the application. As a result of the design made with Fuzzy Logic Designer, the densities and 3D graphics of the outputs can be seen by changing the values of the inputs with the Rule Viewer window. The 3-dimensional graphics of the two outputs in the resulting state are shown in Figure 11. With these values, it can be observed by simulating the results that may occur according to the differences of the values coming from the real-life sensors of the system. The situations that may occur according to several different states of the input values are shown in Figure 12.

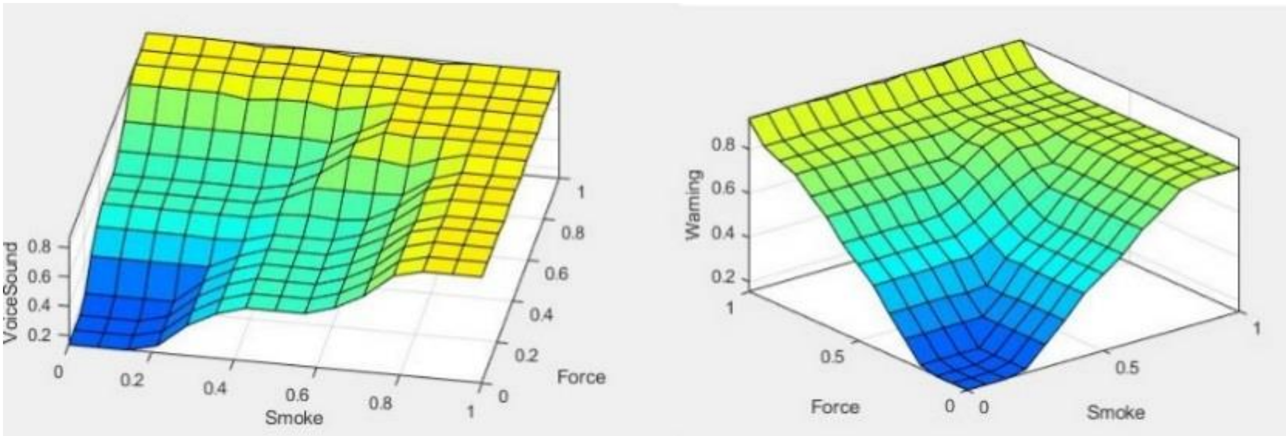

Fig. 11. 3D Graph of Outputs

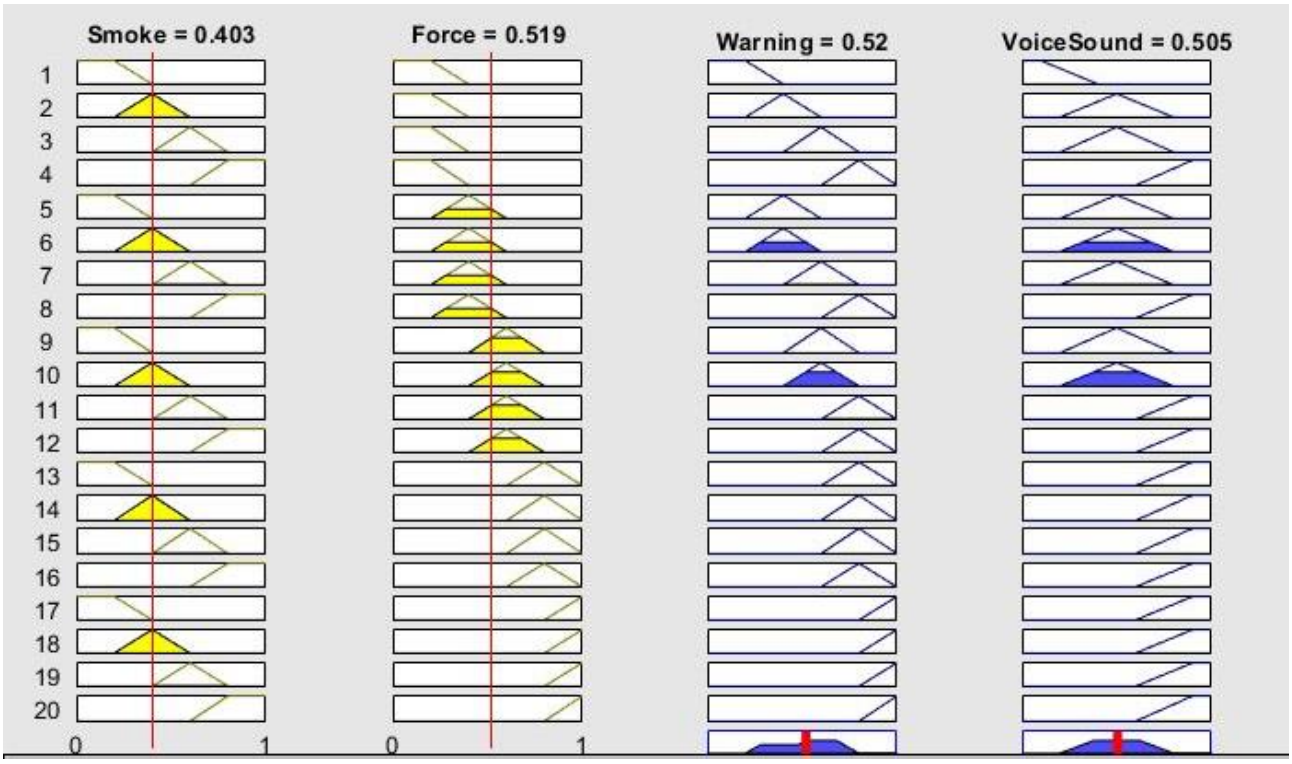

Fig. 12. Display of Inputs and Outputs on Rule Viewer

3. Conclusion

This study focused on the design and implementation of a fuzzy logic-based security system for remote outdoor cabinets. The primary problem addressed was ensuring the security of cabinets located in isolated areas, where traditional security measures may not be sufficient due to the difficulty of physical monitoring. To solve this problem, we designed a system that utilizes sensors to detect smoke and force applied to the cabinet, which are then processed using fuzzy logic to determine appropriate alarm responses, such as activating sound and light warnings. The fuzzy logic approach was chosen because of its ability to handle uncertain and imprecise data, which is common in real-world scenarios like security systems. By creating a set of "if-then" rules and employing the Mamdani method within the MATLAB environment, the system was able to effectively interpret sensor inputs and produce relevant outputs that trigger security alerts.

The results of the system showed that it could accurately assess potential dangers and respond with appropriate warnings, thereby enhancing the security of outdoor cabinets in remote locations. What is solved with this system is the ability to provide an automated and intelligent response to threats, such as forced entry or fire, without the need for constant human oversight. This solution reduces the risk of damage or unauthorized access to valuable equipment housed in these outdoor cabinets.

In terms of future work, this system can be expanded and improved by integrating more advanced sensors or incorporating additional environmental factors such as temperature and humidity. Moreover, future developments could involve connecting the system to a central monitoring unit for real-time alerts and interventions, making it even more responsive and effective in safeguarding remote infrastructures.

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