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Data Center Control Application with Fuzzy Logic

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Abstract

Data centers are systems that host devices utilizing recording and communication technologies, which are expected to operate securely and accurately. Consequently, transforming data centers into smart environments for control purposes has become a significant area of focus. In this study, we monitor the cabinet environment within data centers and ensure that the control system reaches the predetermined optimal state values in the event of undesirable situations. Threshold control was implemented for humidity and flame data, while fuzzy logic theory was applied to temperature data. Fuzzy clusters can be adjusted according to the data center's location at the user's request. This approach allows users to input desired optimal and threshold values into the system, which are then evaluated based on the situation. The designed system ensures data center security with minimal personnel involvement. Additionally, all problematic events are recorded in the system, enabling them to be viewed on a webpage and communicated to designated personnel via email. In the conducted study, the fuzzy-controlled temperature value outputs are reported as heating (40%), cooling (53%), and instances where the system does not perform heating or cooling.

Keywords: *Fuzzy Logic; Embedded Systems; Environment Monitoring; Data Center.*

1. Introduction

Today, the use of computers and the internet is among the indispensables of people. As people's computer and internet usage rates increase, the development accelerates even more. The development of technology has shown its effect in many areas and the machine age has left its place to the age of informatics and artificial intelligence. Hardware, which we define as physical devices, has not remained unfamiliar to this age. As it is seen today, it is not only people who use the element of communication [1]. While the increase in the use of computers and the development of the internet of things brought some needs and wishes of people in their daily lives, the development of computer systems and technology brought these needs together with smart systems and environments.

In order to design smart systems, it is necessary to examine the environmental characteristics. Environments have their own unique standards. Various systems have been implemented to maintain and control these standards. Monitoring the environment data controlled by the sensing devices is called environment monitoring, which helps to monitor the requested data with a software and to run the necessary control and process status on the system [2].

Today, with the developing technology, there is a great increase in the amount of data collected and the issue of data security gains more importance. Since the time we met computers, computer and system rooms have always been seen as a part of the system. Monitoring in data centers; It is a service for security and to detect bad scenarios that may occur beforehand. Apart from monitoring with the help of cameras, it should be monitored that physical conditions may also be included in the system [3].

Microchips or microcontrollers such as Arduino, Raspberry Pi, PIC are widely used for environment monitoring and control in smart environments. In this study, it is aimed to carry out the necessary control process by using Raspberry Pi microcontroller and fuzzy logic structure in order to keep the system at the level of a dark data center without the need for personnel by monitoring the events and situations that may occur in the data centers.

In the second part of the study, similar studies in the literature are presented. The third, fourth and fifth sections constitute the material and method sections. Information about data centers and their features are given in the third section, fuzzy logic method and control in the fourth section, and the software and hardware used in the study in the fifth section. In the sixth chapter, the research findings are given. In the seventh chapter, the results of the study are evaluated and suggestions for future studies are made.

2. Related Works

In the literature, there are many studies on fuzzy logic and environment control. In fact, most of these

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studies are about the management of systems. It has been observed that the fuzzy logic theory is used in different areas, especially in industrial applications. The general lines of our study can be considered as a synthesis of the source research examined.

Most of the studies [4-6] have handled the control of smart environments using Arduino. From similar studies using Raspberry Pi; [7] While making the necessary notifications via WhatsApp messages by reading the temperature and humidity values of the server rooms, [8] the people defined in the system could be informed via e-mail when predetermined alarm situations occurred by monitoring the environment. [8] indicates that the system is not controlled and the optimum situations will be regained only with the help of personnel. It is thought that it will be superior to other studies due to the selection of Raspberry Pi, an advanced microcontroller, in the study.

Studies with fuzzy logic control as a method [5, 9, 10] generally use MATLAB simulation. The use of Python and C# programming languages in system simulation and programming shows that it has a different structure from other products. Since the control factor of temperature and humidity is taken into consideration in the selection of the researched resources, it is seen that control is realized in many industrial areas.

Contrary to the solutions used today, a more economical solution has been presented with the study. As a result of the instant evaluation of the environmental conditions, the monitoring of the environment was carried out. In this way, it is seen that the personnel entrances to the data center will be less, that is, it will become a dark data center. In addition, the reduction of inputs to the environment will indirectly reduce energy consumption to a minimum. The situations and needs that will arise with the designed system were determined in advance, and it was ensured that the personnel took necessary precautions and were informed. It is also obvious that the devices, which have a high cost to install, will be protected and will not harm the institution or organization financially.

3. Data Center

Data center; It is an environment in which data processing devices such as servers, telecommunications and network devices, data storage devices such as data warehouse systems [11, 12], as well as power and air conditioning devices, fire protection and ambient lighting systems are located [13]. Data centers, also called server or system room [14], computer room or data farm [11], show their presence in every field from technology to education, from government institutions to social media [11]. In addition, the systems used in the data center vary according to the processing, transmission and storage of the data [14].

Considering that the data center installation costs are quite high, it is seen that not every business has a data center of its own and data centers are configured in modules [15].

3.1. Data Center Standards

When data centers are examined, design elements such as electrical, mechanical, security, features of the building and rooms are configured differently for each data center [11]. The needs of the design environment realized in the data center have created standards in different ways with the influence of communication design, setting up the environment and quality management [13].

TIA Standart 942

TIA-942, which is determined as the telecommunication infrastructure standard; has a structure that includes the establishment, design and management of the data center [13]. One of the reasons for the existence of data centers is redundancy [3]. Thanks to redundancy, data centers provide greater reliability. Businesses have different levels of available layers for the reliability and redundancy of their data centers [11].

The four-tier data center classification (Tiers), developed by the Uptime Institute in 1993, is a globally recognized and accepted standard in the areas of redundancy, reliability, overall performance and fault tolerance [11, 13, 16]. Tier levels follow each other in the I-IV range. Although the levels are not superior to each other, each level provides the implementation of different types of operations [17].

Tier standards are performance-based, flexible and have a certification that can realize the life cycle in stages. With Uptime certificates, businesses offer an infrastructure service that reduces cost and risk while making them more efficient [16].

Tier standards are given in three different ways as “Design”, “Facility” and “Operations” (**Figure 1**). Design; It is the certificate given to the design documents in which the mechanical and electrical systems, the facility and its architecture are evaluated. Facility; examines that the facility has been established in accordance with the standards. Operations; It examines and reports the operational sustainability and the compliance of the transactions to be performed in the data center with the standards [18].

a b c

Figure 1. *Tier standard and certificate examples [19]*

ASHRAE Thermal Guidelines

The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), whose foundations date back to 1894, publishes a series of standards and guides on HVAC&R (heating, ventilation, air conditioning and refrigeration) systems and their problems. These contents are periodically updated and republished [20]. ASHRAE determined the necessary values for data centers to work with the first version of the guides published in 2004 and the second version in 2008 for data processing environments [21]. With the third edition published in 2011, new classes were added that expanded the temperature range, while the fourth edition, the 2015 guide, expanded the relative humidity values in addition to those published in the 2011 guide. As seen in **Table 1**, temperature and humidity limit values were determined for data centers recommended in the guidelines published in 2004, 2008, 2011 and 2015 [22].

Table 1. *Comparison of environment limits in ASHRAE 2004, 2008, 2011 and 2015 guidelines*

	ASHRAE	2004	2008	2011	2015
Temperature	Lower Limit	20°C (68°F)	18°C (64.4°F)	15°C (59°F)	5°C (41°F)
	Upper Limit	25°C (77°F)	27°C (80.6°F)	32°C (89.6°F)	45°C (113°F)
Humudity	Lower Limit	40% RH	5.5°C DP (41.9°F)	20% RH	8% RH
	Upper Limit	55% RH	60% RH & 15°C DP (59°F)	80% RH	80% RH

3.2. Air Conditioning

Air conditioning is the whole process of adjusting the temperature of the ambient air and reducing the humidity value in the environment.

The fact that the system has more devices affects the temperature and humidity values of the environment and will cause problems in the operation and performance of the system. The stable operation of the devices in the data centers is achieved by the air conditioning of the environment [23].

For the air conditioning of the environment, the limit values recommended in the guidelines published by ASHRAE and specified in Table 1 are used.

3.3. Security

Security is one of the reasons data centers exist. Environment monitoring, fire protection and control of the input and output units are carried out within the security systems [12].

Fire is a big problem that environments should pay attention to. Any fire risk that may occur on data centers threatens the health of not only people but also their devices. Thanks to the detection systems, the pre-detection of the fire informs the formation of the gases that threaten the environment early [24].

4. Fuzzy Logic and Control

4.1. Fuzzy Logic

The solution of many problems that we encounter during the day can be done within the context of previously experienced situations and information. While qualifying as "right" or "wrong" for the solution of some problems, our answer to others may be "partly true" or "partly false". Fuzzy logic, which is a mathematical order, is used to shape an unclear situation [25]. The fuzzy logic algorithm, which is produced as an alternative to traditional and rule-based approaches, can achieve successful results with partial values in cases where the parameters of the problem are not clear. One of the most frequently given examples when trying to understand the basics of fuzzy logic is the weather. There are no two states that the weather is good or bad. There can be many intermediate situations between good and bad. One of the biggest reasons for choosing fuzzy logic in this study is that these intermediate values can be handled with fuzzy logic. The conditions inside the data centers can not only be described as good and bad, but it is aimed that the control center can take different precautionary positions autonomously according to many intermediate values between these two.

4.2. Design and Implementation of Fuzzy System

In systems using fuzzy logic, fuzzy inference process is examined in three main steps. These are blurring, fuzzy inference and defuzzification as seen in **Figure 2**.

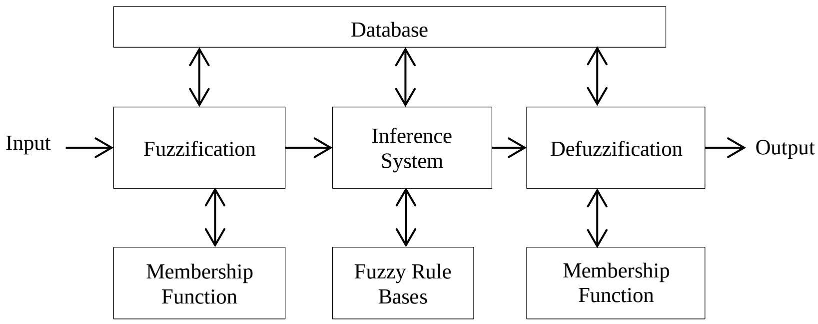

Figure 2. *Fuzzy logic system architecture*

Fuzzy subsets are created by matching the real data entered in the blur unit in the system architecture with fuzzy variables [26-28]. The subsets created by the membership function show a membership degree in the range of 0 – 1 [5, 29]. After fuzzification, fuzzy inference system is performed. In this unit, a decision is made about which rule is related to values and which one will be selected from the set of rules formed during fuzzification [30, 31]. The final stage of architecture is defuzzification. In the defuzzification system stage, the fuzzy inference system outputs are converted to a real value [26, 32].

5. Hardware Infrastructure

Data center control application; Raspberry pi is designed by developing temperature-humidity and flame sensor, peltier, fan and web interface. While the Raspberry Pi hardware was written with the Python program, the development of the web interface was provided with ASP.NET MVC. It shares a common database prepared with web interface and Raspberry pi MSSQL. Operations on the database are provided by web services using HTTPOST and HTTPGET structures.

6. Experimental Setup

Thanks to the sensors in the cabinets in the data center, the data was received and sent to the database with the Raspberry pi. In order to control the temperature of the center, rules were created by writing a fuzzy logic mechanism. Peltiers used for heating and cooling operate in line with these rules. If the humidity information in the system exceeds the threshold value, the fans operate and ventilate. In addition, possible fire situations are recorded with the flame sensor in the environment. Information is given to the determined personnel through the e-mail service included in the web interface of the system, which is seen and explained in **Figure 3**, in certain situations. While designing the interface, the interface library/framework created in the Koçak [4] study was used. In addition, fuzzy equations and calculations suitable for the data center control problem were performed on the server side using C# programming language.

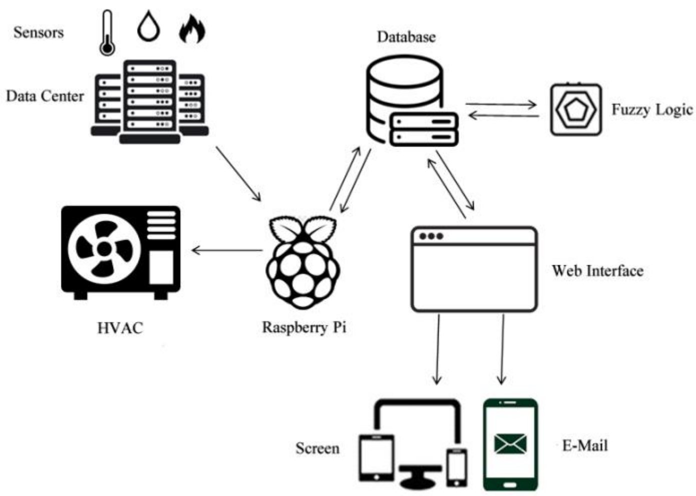

Figure 3. *Working principle of the system*

6.1. Fuzzy Set

"Hot, cold, little, much, extremely, a little, etc." that people use to explain certain situations and events in their living spaces. Expressions such as have a fuzzy state [4, 33]. Thus, the fuzzy expressions allow us to create fuzzy sets.

The lowest temperature measured between 1927-2021 in Turkey was -24.9℃, and the highest temperature was 41℃ [34]. On the world, the lowest temperature was recorded in Greenland with -69.6℃, and the highest temperature was recorded in Jordan with 58℃ [35]. The lowest and highest temperature ranges given in Table 2 have been determined based on the temperatures felt throughout Turkey and the world.

As seen in **Table 2**, fuzzy set expressions do not have a definite inference. For example, 16℃; It is in both the warm and slightly cold range. The rules created by the fuzzification process are evaluated and as a result of the inferences, the warm or slightly cold ranges are determined proportionally. If 30% is a little cold and 70% warm, different transactions can be created as a result of the transactions and membership values. **Table 2** emerges when the temperature values are considered to be matched with fuzzy expressions.

Temperature ranges are specified in the widest range and can also be evaluated regionally. The purpose of creating this chart is to determine the current situation by blurring the temperature ranges.

Table 2. *Fuzzy set representation of temperature ranges*

Fuzzy Set	Temperature Ranges
Extremely hot	50-70℃
So hot	35-55℃
Hot	28-45℃
A Little Hot	23-30℃
Warm	15-25℃
A little cold	10-18℃
Cold	8-13℃
So cold	0-10℃
Extremely Cold	(-70)-7℃

6.2. Membership Functions

Triangle membership function is used while creating membership functions in the interface. There are three variables in the triangle membership function. These; indicated as the start (a), the highest (b), and the end (c). μ(x) represents the calculated membership value for each element. Triangular membership degree was calculated as seen in Eq. (1).

$$\mu(x;a,b,c) = \begin{cases} x \gg c\,, x \ll a \rightarrow\ 0 \\ a < x \ll b \rightarrow \frac{x-a}{b-a} \\ b < x < c \rightarrow \frac{c-x}{c-b} \end{cases} \tag{1}$$

6.3. Fuzzy Rules

In the designed data center control system, there is no need for any changes on the source code with changes such as adding and removing through the interface. Rules are generated using the multiple-input, single-output (MISO) method. This method is illustrated by Eq. (2).

$$\text{If } X_1 = A \text{ and } X_2 = B \rightarrow Y = C \tag{2}$$

The X values in Equation 2 represent the inputs, the A, B and C values represent the states, and Y represents the output. In order to reach the Y output, A and B values must be calculated first. For each entry, it is necessary to find out how close to the statuses to be calculated, to be a member. As an exemplary rule, if the cabinet rear temperature is "Hot" and the cabinet front temperature is "Warm", let the output be "Cool". For the warm and warm expressions in this example, the membership degree of the cabinet rear and cabinet front temperature values is calculated with Equation 1. With the expression in Eq. (3), it is calculated which rule gives an output with the help of cabinet rear and cabinet front temperature membership values obtained from Eq. (2). The fuzzy set membership degree calculated with the help of this rule is truncated with the MIN-MAX method and the output value is finalized with the weight average method.

$$Y_i = MIN\left[\mu_{x_1}(x_1),\ \mu_{x_2}(x_2)\right] \tag{3}$$

The Y value given in Eq. (3) shows the output value *i* by calculating separately for each rule. The x values represent the inputs, while the μ(x) represent the mean. **Figure 4** shows an example graphic representation.

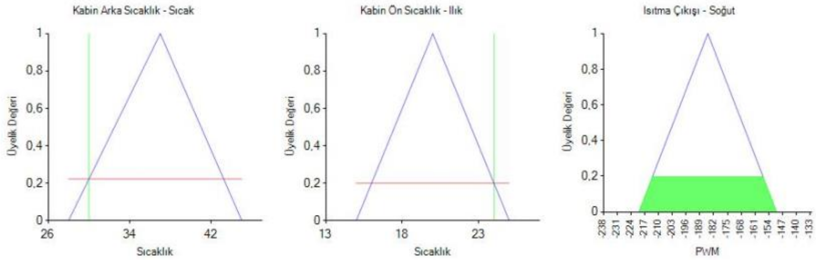

Figure 4. *An example fuzzy output graph (X1=30, X2=24)*

For the output seen in **Figure 5**, the calculation was made using Eq. (4). Each rule formed like the expression exemplified in **Figure 4** is included in the calculation. In Eq. (4), Y represents the output value, X the input value, and $\mu_n(x)$ represents the membership value calculated for each n value. As can be understood by Eq. (4), an output is produced as a result of these calculations by using the weighted average method.

$$Y = \frac{\sum_n \mu_n(x) * x}{\sum_n \mu_n(x)} \qquad (4)$$

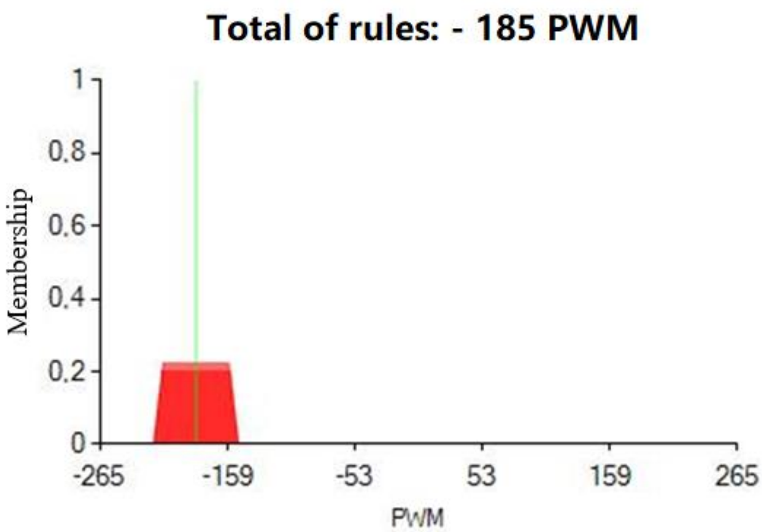

Figure 5. *An example rule sum post output graph*

6.4. Fuzzy Rules Table

Table 2 fuzzy set was used in the formation of fuzzy rules. A fuzzy rule table was created by defining 81 rules in total by matching the cabinet rear (9) and cabinet front (9) temperatures with fuzzy set.

6.5. Code Measurements

Software applications have tools that can prevent complexity with a secure and sustainable structure. With these tools, the developers monitor the problems that may occur and the development of the software being worked on [36].

Visual Studio 2019 application was used in the development of the web interface. With the Code Metrics tool included in the application, the maintenance index, cyclic complexity, inheritance depth, class link, source code lines and executable code lines are calculated. Calculated situations are shown in **Table 3**.

Table 3. *Code measurement results*

Maintainability Index	Cyclomatic Complexity	Depth of Inheritance	Class Coupling	Lines of Source code	Lines of Executable code
90	280	3	75	1284	402

Maintainability index; It represents the ease of code maintenance. A value in the range of 0 - 100 is calculated. If the calculated value is 20 and above, it is stated that there is a better ease of maintenance with the green color [37]. The fact that the maintenance index shown in Table 4 shows the value of 90 shows that it has a high ease of maintenance.

Cyclomatic complexity; Specifies the number of flow control mechanisms in the program. A range of 1-10 indicates a low risk, 11-20 indicates medium, 21-50 indicates high, and above 50 indicates a very high risk [38]. Although it is seen in Table 4 that the cyclomatic complexity is 280, this number represents the sum of all forms and pages. When the pages are evaluated individually, only one of the 307 values is at medium risk, while all other values seem to be at low risk.

Depth of inheritance; measures the object inheritance hierarchy. A low depth number indicates less complexity [39]. As seen in Table 4, it has a less complex structure.

Class coupling; shows how many classes are used in a class. A high value indicates that the classes interact more with each other [40]. Table 4 shows that the class coupling is 75. This number shows the total used class items, and it has been observed that it does not exceed the critical value when viewed individually.

Lines of source code specify the integer numbers of lines in the source code, while lines of executable code give the approximate number of executable processes or lines.

6.6. CPU Usage

Events, memory usage and CPU usage measurements are made with the diagnostic tool of Visual Studio 2019 application. Thanks to this tool, the performance of the designed interface can be measured. When the interface performances are examined, the highest category is IO (Input/Output) with 44%, followed by JIT (Just In Time) compiler with 32%. Data on CPU usage is shown in **Figure 6**.

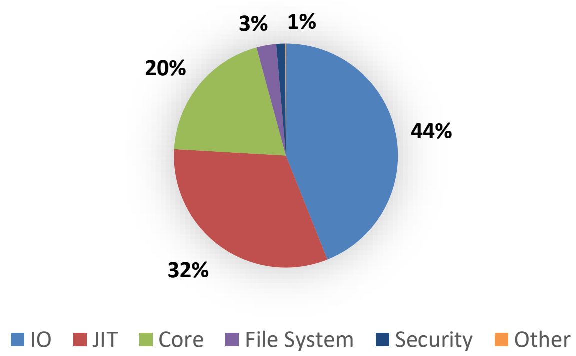

Figure 6. *CPU usage analysis top five categories*

6.7. Scenarios

Two different scenarios were considered in order to observe the working order of the designed system. With the scenarios written using VS.NET C#, the outputs of the system to be given by the method have been observed.

<u>Scenario 1:</u> The cabinet front temperature value, which represents the ambient temperature, is gradually increased linearly.

Output value of ambient temperature data given by fuzzy logic method is shown with PWM signals. The output values against the temperatures given for the scenario are shown with the PWM-temperature graph seen in **Figure 7**. Output signals give an output in the range of (-255) – 255. If the given output value has negative values, the cooling process must take place. Values where the system does not make heating or cooling and the ambient temperature is between 18-23 show the range in which the fuzzy method does not output.

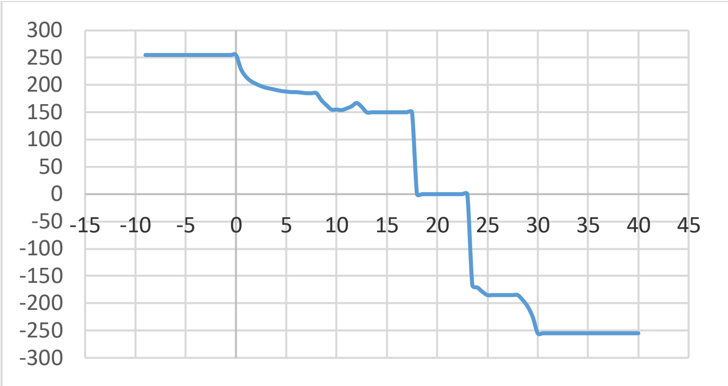

Figure 7. *PWM-temperature graph*

Scenario 2: In the case that the front temperature of the cabinet, which is the ambient temperature, increases linearly, the value of the cabinet rear temperature is increased in a parabolic way.

When the data of Konya province belonging to the General Directorate of Meteorology are examined, the range of (-10) - 40 is used for the web interface, based on the lowest and highest average values [41]. According to the scenario, the temperature was increased by 0.5 increase to the cabinet front temperature value. For the cabinet rear temperature, the increase amount is added with a decreasing value. The 1.0 increase value given for the cabinet rear temperature is determined by 0.0075 value decrease in each reading.

According to the scenario, the PWM output produced by the system was observed after the fuzzy logic process of the cabinet rear and cabinet front temperatures, which were examined in the simulation. Output values produced for cabinet rear and front temperatures are shown in **Figure 8**. When the observation data are examined, it is seen that no PWM output signal is produced at the temperature of 12 in the cabinet front and 26,905 in the back of the cabinet. Signal values are given as output for cooling and heating processes, albeit slightly at other temperature values.

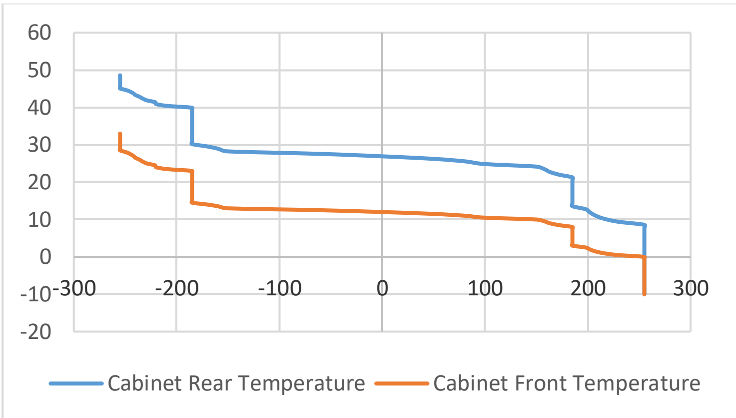

Figure 8. *PWM outputs produced for cabinet rear and front temperatures*

Scenario 3: The front and rear cabin temperature values were given to the system and a comparison was made.

The temperature values specified in Table 2 are given for the front and rear cabin temperature values. It has been determined that a total of 225 PWM signals are output by matching the cabin rear (15) and cabin front (15) temperatures within the specified (-70)-70℃ temperature range. These output signals are divided into heating (91), cooling (119), and HVAC system not operating (15). The temperature comparisons for heating (dark color) and cooling (light color) processes are shown in **Figure 9**. In addition, the sizes of the bubbles seen in **Figure 9 (a)** are specified according to the PWM signal values produced for heating and cooling. The representation of the generated signal values is shown in **Figure 9 (b)**.

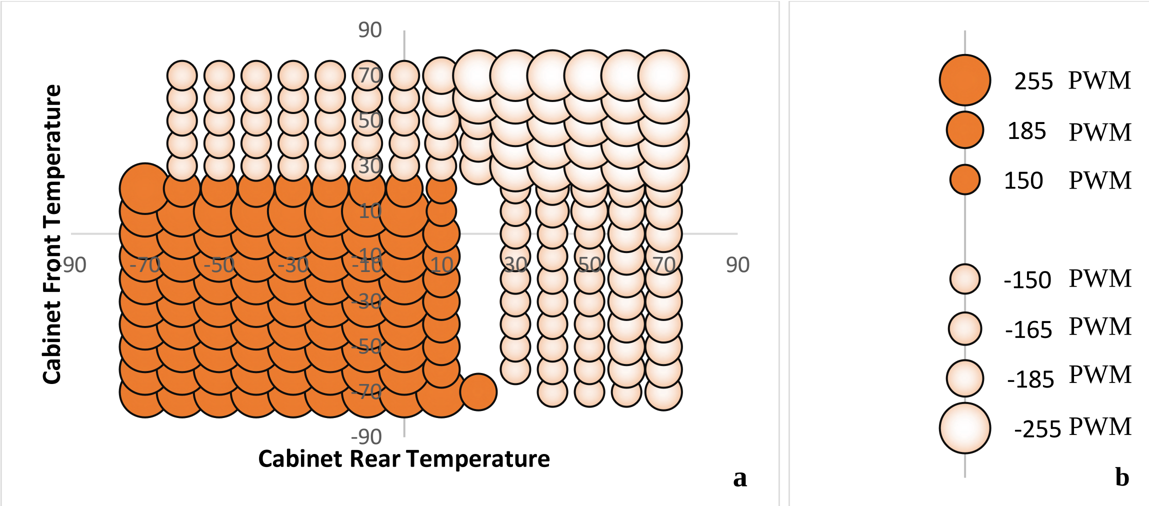

Figure 9. a) *PWM signal distributions according to temperature values* **b)** *The sizes of bubbles*

In **Figure 9 (a)**, the bubbles belonging to the cabin back temperature (20) and the cabin front temperature (40) value generate the -185 PWM signal as the system output value. With this value, it is seen that the cooling process is performed. As another example, 185 PWM signal is generated as the bubble output value of the cabin back temperature (10) and cabin front temperature (0) values. In this case, the heating process of the environment was performed.

Scenario 4 (Non-Fuzzy): Ambient humidity is linearly increased and decreased.

The output value given by the operation of the fan in the system is shown with PWM signals. The output values against the humidity values given as per the scenario are shown with the PWM-humidity graph in **Figure 10**. Output signals give 0 and 250 values. The threshold value was previously set as 50 by the user in the web interface. As can be seen in **Figure 10**, as a result of exceeding the threshold value of the humidity data of the environment, the PWM signal gives a value of 250 and enables the fan to operate. When the ambient humidity value falls below the threshold value, the PWM signal gives 0 value and the fan is stopped.

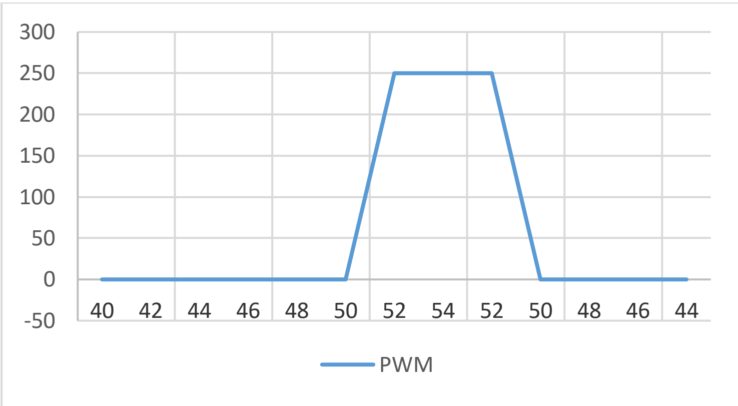

Figure 10. *PWM-humidity graph*

Scenario 5 (Non-Fuzzy): Any flame condition that may occur in the environment was observed with sensors.

The data received with the flame sensor in the environment is included in the system without the fuzzy logic method. By monitoring the system continuously, "There is a flame" or "No flame" warnings can be displayed on the interface in case of any flame that may occur. The outputs that may occur when a fire-like object is included in the system as per the scenario are shown in **Table 4**. As seen in **Table 4**, when the flame object is included in the system, the "Fire Detected" warning and the start and end times of the warning are also displayed. In this way, it can be reported how long the system has been exposed to fire.

Table 4. *Fire situation report*

Flame Detection	Start	Stop
Fire Detected	22.08.2022 14.17	22.08.2022 14.25

Fire Detected	13.08.2022 13.23	13.08.2022 13.31
Fire Detected	03.08.2022 12.34	03.08.2022 12.40
Fire Detected	16.07.2022 22.52	16.07.2022 22.57
Fire Detected	16.07.2022 11.08	16.07.2022 11.13

7. Discussion

There are many studies that perform data center control from industrial environments where control is performed. When the materials and methods used in the studies are examined, there are differences in the selection of the microcontroller, the programming language used and the method.

As a result of the literature research, it has been seen that the control controllers encountered in the data center are generally Arduino [5, 6, 42] and Raspberry Pi [6-8, 43]. Mostly Python [6-8] and MATLAB [5, 9] were chosen as programming languages in the system. The fuzzy logic chosen as the method has been applied less in the literature [5, 42, 44, 45] than the classical method in data centers.

Some situations encountered in the literature review and system adequacy and deficiencies were compared. In the designed control system, materials used more in data centers were selected in the literature review. It can be considered as an original work since there is no other study of the system using more modern programming languages and materials and fuzzy method selection.

Thanks to the fuzzy logic chosen as the control method, instead of heating or cooling the environment at an optimum temperature, how much it should be heated or cooled is automatically calculated according to the written fuzzy rules and variable temperature conditions. The fuzzy logic selection of the system instead of the classical logic creates a more qualified control in order to keep the environment at the optimum temperature.

Worldwide temperature values are variable. While 40 degrees is considered hot according to some geographical regions, according to some regions, this value is within the seasonal normals. For this reason, the optimum levels of data center installation needs may vary according to the environment. System values can be redesigned by examining the geographical conditions of the data center with the designed interface. Reshaping the place where the center is located according to the seasonal normals also ensures that the system is less damaged and uses energy.

8. Conclusion

In this study, necessary structures have been created for autonomous control of the data center with fuzzy logic. The Raspberry Pi used in the study is coded with Python. Temperature, humidity and flame status values were captured in ten-second intervals by sensors in the data center. One flame, one humidity and two temperature sensors are used in the system. Thanks to the fuzzy logic set, the captured temperature value is interpreted in the web interface written in C# and the possible states of the system are calculated. After the calculated situation, he gave command to the HVAC system and focused on keeping the system at the optimum level by heating and cooling. In case the humidity value is exceeded by the threshold value entered by the user from the web interface, it is desired to reach the optimum level by sending the PWM signal of the fan included in the system. When the system is observed at runtime, it is seen that the special case control, such as the fire situation, which was previously performed manually, is automatically managed by the developed application. Values taken from all sensors are kept on MSSQL database.

Data center temperature and humidity values are desired to be kept at optimum levels. Values were taken from temperature, humidity and flame sensors in the system. Fire detection for flame value, threshold value comparison for humidity value and fuzzy logic method for temperature values were used. The web interface designed in the study has a plain appearance away from complexity with ASP.NET MVC. The user gives an output corresponding to the values taken from the sensors with both the manual method and the fuzzy logic method. The synchronization of the sensor data received from the system and the determined short intervals followed the system with minimum delay. Any problems that occur in the system are recorded in the database and instant notifications are made to the users. In order to send the notifications to be made during the operation of the system, the administrator mail and the mailing list to be sent are saved from the web interface. Thus, possible situations such as temperature increase and decrease, and exceeding the humidity threshold value were informed to the people who should be informed by e-mail communication.

In line with the scenarios realized in the system; the fire situation was informed and the operation of the system was tested. When the humidity threshold value is exceeded, the fan is operated until the specified normal conditions are met. It has been observed that the fuzzy logic system responds to the values received from the temperature sensors, such as heating or cooling, according to the incoming values.

In this study, it is foreseen that the system will have a longer life due to the automatic management of the control mechanism and the control of it without causing any damage.

In studies to be conducted on data center management, it is recommended to consider the average temperature and humidity values throughout the year according to the geographical location of the data center.

In order to achieve more successful results in future studies, the system is planned to be built in larger data centers with more cabinets and devices. In Addition, incorporating machine learning techniques alongside fuzzy logic could potentially improve the system's adaptability to changing environmental conditions and enhance its overall performance. By learning from historical data and adjusting its parameters, the system could become more efficient in detecting and addressing undesirable situations in the data center.

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