ISSN 2347 - 3983
Volume 8. No. 5, May 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter66852020.pdf
https://doi.org/10.30534/ijeter/2020/66852020

Fuzzy Logic Temperature Control: A feedback control system implemented by fuzzy logic

Aaron Don M. Africa, Arl Marion Josef L. Divino, Kyle Austin B. Hartigan-Go
De La Salle University, Manila
2401 Taft Ave., Malate, Manila 1004,
Philippines, aaron.africa@dlsu.edu.ph

ABSTRACT

This paper is meant to highlight and discuss the facts and uses of fuzzy logic in terms of a temperature controller. The purpose of this temperature control system is to heat a room to a specified temperature then tries to maintain it at that temperature in a controlled manner. This paper will highlight different possible concerns done in the system and possible solutions to this fuzzy logic pattern. The applications are far-reaching as the temperature control can be depicted and used in multiple control systems such as control temperature in air conditioning units, generators, temperature for aquariums, etc. All these applications with fuzzy logic can help dictate the amount of energy used constantly to save power while achieving the needed amount. The fuzzy logic in temperature control systems can vary and the truth table for the logic system may vary widely as well. However, the main point of the system is to create and apply control correctly. By making use of built-in functions that can potentially correct errors and predict patterns in terms of date and time of the year, the time of the day and the flow of air, etc. It can effectively correct and make adjustments for the temperature correctness.

Key words: Fuzzy logic, Temperature control, feedback system, control system.

1. INTRODUCTION

Fuzzy logic is a form of representation of knowledge suitable for concepts that can not be defined exactly but also depend upon their contexts. With fuzzy being defined as something not clear, distinct, or precise or something that is blurred [1]. The human brain can comprehend uncertainties, vagueness, and judgments, and computers can only play around precise evaluations; fuzzy logic is the process of mixing the two techniques. Fuzzy logic differs away from classical logic with statements that are no longer yes or no, high or low, or true or false [2].

In the fuzzy logic, it tries to simulate the decisions that can be done by humans through the use of truth table or values which symbolizes yes or no, one or zero, These symbols can create rules and possible parameters through a rule-based automatic controller, which establishes these rules. These rules following the creation of the parameters as it sets up follow a nonlinear mapping and following this will perform actions based on these rules. These systems are based, as stated above in rules or principles based on uncertainties and probabilities based on the given task it must accomplish. With certain statements being true it must establish correct to a certain degree or fold [3,4].

Object classes in the real physical world more often do not have precisely defined criteria of membership, as there would be some as animals such as dogs, cats, etc as its members and exclude trees, stones and such as its members although such objects as starfish, bacteria have an ambiguous status with how they are classified concerning the term or class of animals and the same kind of uncertainty comes up in the case of a number such as 20 about the “class” of all real numbers which have a value greater than 1 [5].

2. BACKGROUND OF THE STUDY

Implementing a temperature control system is something not new today as it is presented in most smart homes nowadays. With smart TVs and smart air conditioning units, these are just some of the everyday appliances that people use as a basic commodity. Applications of temperature controls at home not only apply to AC units but also to fridge, heaters, boilers, and humidifiers in the house [6]. Applications of the temperature control can also apply elsewhere too. Such as greenhouses wherein the application of the services is paramount in the survival of the plants especially in colder or warmer areas with plants that are relatively fragile and difficult to keep alive. Meanwhile, in factories and power plants, generators must be kept not beyond certain temperatures lest it may overheat and damage the system [7].

These systems provided can be made use of to create and help in the creation of works that can be applied in all scales of applications. As seen, being able to be more efficient in the application of temperature control materials can also affect the power usage and consumption simply by being able to constantly what is a comfortable temperature for home air

conditioning units, it can provide far more effective means of efficient energy management and also temperature control by taking into account the presence of humans in there. With humidity sensors also affecting temperature, it is far able to give a comfortable experience while not needing human interactions with it. Minimization of human interaction provides less room for error and can create ideal situations or scenarios that can also deal with environmental inputs such as the current temperature outside, humidity lighting, etc. This way, it also positively affects greenhouses in terms of fuzzy logic automation of the temperature control as plants tend to thrive far more in certain humidity or atmosphere. As such it can create and enhance the production of the greenhouses by assisting in the growth of the vegetation of the system.

3. STATEMENT OF THE PROBLEM

In this journal review Esque document, the problem for the usage of the fuzzy logic system to function effectively in the temperature control systems settings. With this, however, making use of the fuzzy logic can be dependent on multiple scenarios and variables which can change the outcome of the problem. Fuzzy logic follows a certain rule of uncertainty and uses the basis of a percentage to function properly in the problem. So by assumption, through the collection of the variable, the program control system should be able to correctly predict wherein the considered rhythm or flow of temperature needed to optimize the temperature being required. These variables can be humidity, current outdoors and indoor temperature, dust in the air, the flow of air, etc. And the speed of transition or change of temperature can be another deciding factor in how the flow is improved. These are parts or systems that may change depending on location and atmosphere and vertical height of the room. As such the table fuzzy logic table must be able to handle all of these variables.

The everyday life of a human, with the sudden increase and decrease of ambient or room temperatures to our surroundings especially with the effect of global warming with it, increases the temperature of our surroundings by at least 2 degrees centigrade in the next century [8], which could be even faster nowadays with how low-class companies still take advantage of gas-powered machinery without proper disposal of fuel deposits, not everyone can adapt to the sudden rampant changes in the temperature of the room they are currently in, also at the same time we do not always know the exact temperature by measurement as we do not always have the tools to measure this exactly [9].

With this, we are going to apply a fuzzy logic controlled temperature control system as there would be a set range for what is ‘hot’ for an individual or a group of people to be able that the room air conditioning or whatnot would adapt to what is needed at that time disposal [10,11].

4. SIGNIFICANCE OF THE STUDY

A fuzzy temperature control and recovery system is not new in the industry as it proves useful in many fields with not only for a room temperature control system but also for monitoring of industrial equipment, plants, etc. [12, 13, 14, 15]. Not all of these used a fuzzy logic system since they would rely more on precision as these objects most likely need accuracy concerning operating temperatures and whatnot [16]. The average human being has no bearing for an actual temperature reading, but people tend to say what they feel for an environment such that it’s ‘too hot’ or ‘too cold’ for the current temperature, this is where we had to input a fuzzy logic implication instead with the usual direct data manipulation with a certain temperature to operate the system to either cool down or warm up the room.

The system application would deem useful for other applications and the successful implementation of this kind would be good proof to show the effectiveness of such systems. [17,18]. A properly temperature-monitored environment is ideal especially for the medical field as some patients would need that they be in a temperature-specific place depending on their medical condition as their bodies may react badly to sudden changes of temperature or with how the room may not go together with the external environment sudden changes of climate [19, 20].

As seen in the introduction and background of the study, the main significance of the study is that the quality of the temperature can depend on a lot of things and that through the improvement of the factors such as the efficiency of the usage of air conditioning units, etc. It can greatly affect the comfortability of the person or home in a question/ These control on materials can help in the fridge heater, boiler humidifier systems and air conditioning units in a home. Combined with the Internet of things approach, systems could be created wherein it can quickly turn on and be ready and correct the temperature at the correct time or by the time the owner reaches the home. Another point of the statement is that the fuzzy logic can help in the growth of vegetables by always changing the temperature to the ideal temperature of the vegetable. As vegetables grow, they are subject to varying temperatures, humidity, and even weather of the outdoors. By placing it within a greenhouse the temperature can be changed to favor the growth of the vegetable. However, temperature change still affects whatever the temperature of the greenhouse is. As such, it may help in consistently changing the temperature of the system by providing a fuzzy logic control system that can control the temperature without the need of the owner having to constantly check for the optimal temperature.

5. DESCRIPTION OF THE SYSTEM

The system would operate with a temperature sensor to be able to get data on the current temperature data inside the

room which can be done with a DHT module so sufficient data can be gathered together with humidity readings as well. Then the data would be processed by a small microcontroller programmed with fuzzy logic code implementation then this microcontroller controls the airconditioning system with the feedback controller to guarantee the desired response of the output. Figure 1 shows the Flowchart of the Feedback System.

6. METHODOLOGY

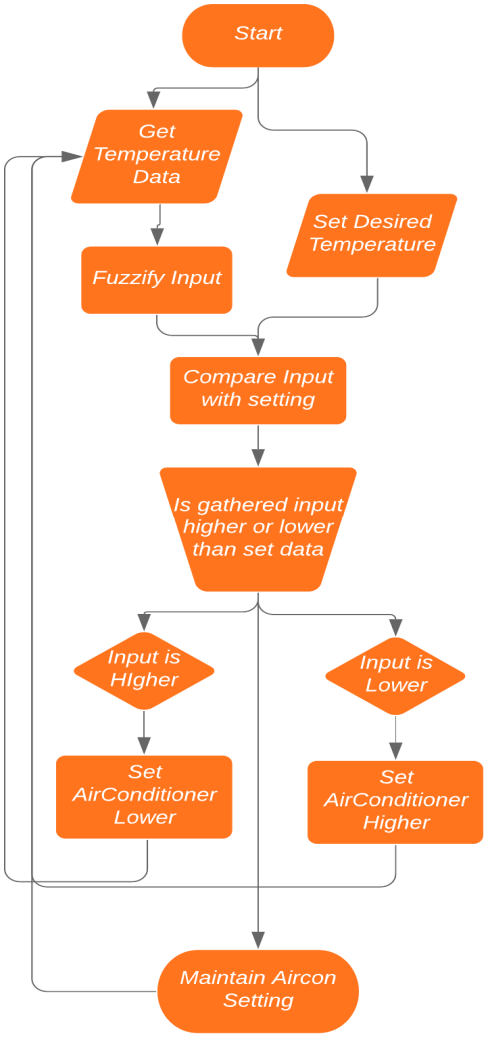

Figure 1: Flowchart of Feedback System

The system would generally have two inputs where one would be user-inputted as to set the temperature setting desired then the second input would be sensor-collected data for a more accurate data gathering (figure 1). Then this sensor-collected data would now be fuzzified to be able to compare it with the fuzzy rules then proceeding to the proper feedback response from the fuzzy rule output then the process continues for it to continuing gathering data to be able to maintain the chosen temperature setting.

7. REVIEW OF RELATED LITERATURE

This part of the paper aims to discuss more of the terms that are going to be used for this paper with the help of supplementary papers and other journals presented in this part. The pieces of literature reviewed were mostly somehow a direct implementation of a system which would be highly similar to what our proposed system going to be, with it being a temperature control system managed by a fuzzy logic controller to be able to maintain the output at the desired level of either hotness or coldness

7.1 Temperature Control System using Fuzzy Logic

This document implemented a low-cost temperature control system with the use of a 4x4 keypad, an lm35 temperature sensor, and an analog to digital converter to convert the analog value into digital and feed it into the fuzzy controller with an LCD to display current values. The controller then calculates the difference among the set values and the current values while considering as an input variable of the fuzzy logic, by the process of fuzzification, the controller then calculates its membership. The rule base in an inference system outputs the membership value that was previously calculated. The defuzzification now comes into place where it calculates the actual value of the pulse width modulated output, which becomes an input now, for the heater and the fan which is the output of the control system. The process is composed of a heater, fan, and temperature sensor, with the amount of current flowing through the coil being the deciding factor of the temperature of the thin metal plate. The fan is now placed strategically near the heating element while the amount of power delivered to the heater and the fan will now be controlled through a set of code inputted into the microcontroller serial port. The microcontroller now outputs the pulse width modulated signal into the MOSFET to deliver the desired voltage level for sufficient powering the heater and fan.

All these were implemented without the need of a special software tool unlike most fuzzy controllers with numerous rules running on a computer system, a unique fuzzy logic controller was used with a small number of rules and simple implementations demonstrated to solve a temperature control problem with various dynamics or variable time delays commonly found within the industry.

7.2 Fuzzy Logic Based Water Bath Temperature Control System

The research objective was to implement a fuzzy logic controller for a temperature control system, the process used is one of the commonly used processes being implemented currently in the industry, a Water Bath Temperature control system [21,22]. The system consists of a water tank where the cold water enters from one side of it and hot water should be leaving the other side with the aim to have the output water at a targeted temperature by the user. A set of assumptions was done as well, the volume of the water tank should be at a constant level, the inlet flow rate should equal the outlet flow

rate, there should be no change of state and uniform temperature should be maintained inside the tank.

The implementation of Fuzzy Logic is deemed to be more effective when it comes to control systems and much easier as well. A fuzzy control system is divided into a single variable control system and the multiple variable control system as the water bath temperature controller uses a two-dimensional fuzzy controller. The system also has two input variables: error, E and change of error, dE, and one output variable, U. The computation structure of the fuzzy logic controller scheme is composed of fuzzification, the interference system then the defuzzification where the input to the fuzzy control system, would be the error and the change in error which are then computed from the referenced output.

All of the membership functions for the controller inputs, error, and change of error, and the incremental change in the controller output for the fuzzy logic system are then defined on the common interval, a gaussian membership function was used with equal base and 50% overlap with neighboring membership functions.

The executions of the system were now simulated through MATLAB with the objective goal. The system had presented the Fuzzy logic output where all of its gain parameters can be simultaneously tuned for a bathwater temperature process where the performance indices used was straight to the point and concise, yet all these yielded satisfactory results from the system response point changes and any other sudden disturbances possibly coming.

8. THEORETICAL CONSIDERATION

8.1 Fuzzy Logic

Fuzzy logic is a form of representation of knowledge suitable for concepts that can not be defined exactly but also depend upon their contexts. With fuzzy being defined as something not clear, distinct or precise or something that is blurred. The human brain can comprehend uncertainties, vagueness, and judgments, and computers can only play around precise evaluations, fuzzy logic is the process of mixing the two techniques. Fuzzy logic differs away from classical logic with statements that are no longer yes or no, high or low, or true or false. With Fuzzy Logic, linguistic variables are to be used which are the input and output variables of the system whose values are sentences or words from a natural language instead of the conventional numerical values. A linguistic variable is usually generally decomposed into some sets of linguistic terms such as short, average, tall; cold, cool, warm, hot; very low, low, average, high, or very high. The concept of a fuzzy logic system was conceived by Lotfi A. Zadeh, a professor from the University of California in Berkley, and he presented not as a way of control methodology but as a way of processing data and what not by allowing partial set membership rather than the crisp set membership or non-membership. This approach with set theory was never applied to control systems until the 70's due to insufficient small computer capabilities before that period. Professor Zadeh had reasoned that people do not need precise, numerical information input and yet they are capable of high-adaptability control in their everyday life.

8.2 Temperature Control System

The temperature control system could be implemented with a Fuzzy Logic Controller (FLC). With conventional controllers being derived from control theory techniques while being controlled. Since the last two decades, there was already a substantial amount of research in the field of control of non-linear systems with fuzzy logic implementations.

9. DATA AND RESULTS

Figure 2 shows the Fuzzy logic idea

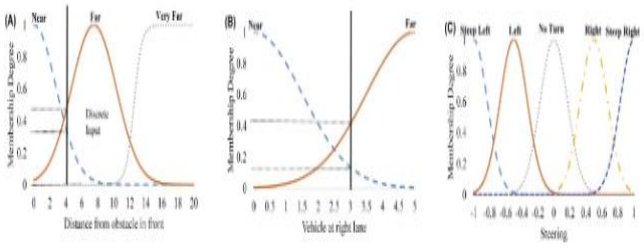

Figure 2: Fuzzy logic idea

Figure 3 shows the temperature of the Control System.

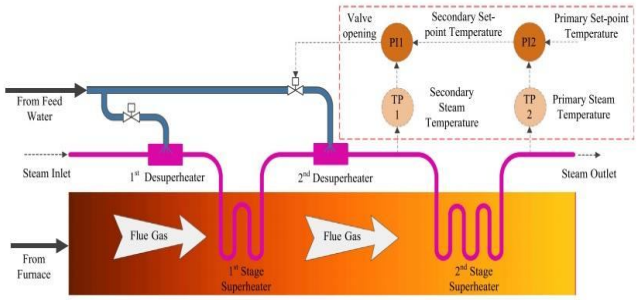

Figure 3: Control system temperature

Figure 4 shows the Control Block Diagram.

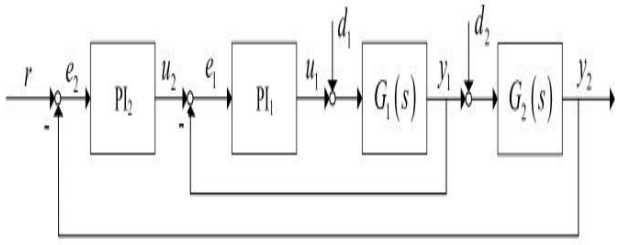

Figure 4: Control Block Diagram

Figure 5 shows the Control Graph of the System.

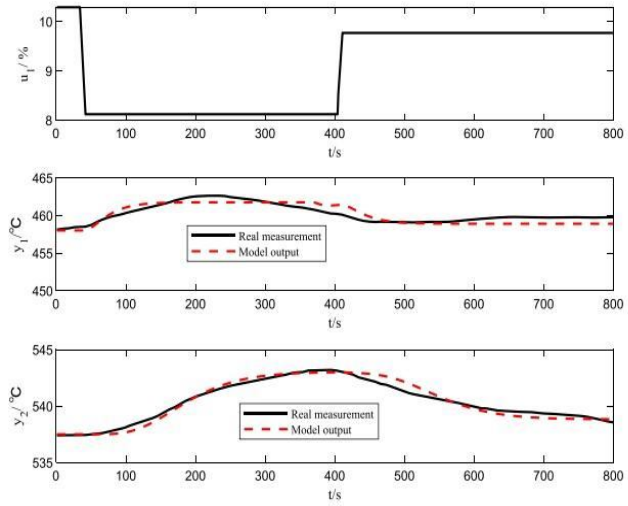

Figure 5: Control Graph of the System

Figure 6 shows the Feedback Control Diagram.

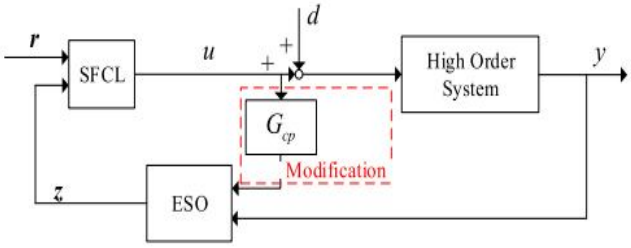

Figure 6: Feedback Control Diagram

10. ANALYSIS OF DATA

For the first image, it simply highlights how the fuzzy inference system works. The fuzzy inference system or the FIS is a system that uses fuzzy set theory to map certain inputs and correlate them to outputs that create a sense of detail and classification. It helps in the creation of details and applications in the system.

For the control system temperature, this simply shows about a lump of coal-fired power plant that changes its load for regulation and model systems the creates a closed-loop system to create the needed changes. This closed-loop system is meant to handle the modeling of uncertainties. Possibilities' wherein there are strong variations in the system. As such the system is prepared for strong nonlinearity of load caused by the variation of the system and the possible effects in control performance

The third shows the higher-order system of dynamics of the second super heater which can lead to a slower response to disturbances. Although still able to determine and change base on the temperature changes that it needs can still cause unnecessary stress towards the entire system.

The disturbances in the SST system are multi-sources. The factors which can determine the load demand, stream flow, and combustion can determine and influence the main steam temperature. As stated above. It can determine and change the fuzzy logic as such the fuzzy logic must have the necessary tools to adapt depending on the circumstances and the possible changes to temperature due to the changes of multiple factors [23,24].

Finally, the model is hard to build due to the complexity of the system as such the controller system of the SST control system should and must ensure a strong ability to combat disturbances and be highly adaptable to changes and a certain amount of good robustness to create a strict mathematical model. This system follows the logic patterns in the study of [25,26,27].

11. CONCLUSION

As seen as the example in data and analysis and conclusion. In all types of systems, there can be a great number of possibilities of disturbances errors, factors, and variables that can affect a system. Due to this, there must be a way to make do with all of these variables within the system. Creating a fuzzy control must force the system to make do and have a larger truth table to make up for all the possible variables.

All of the unseen variables must also be taken into consideration. Although taking the fuzzy logic on the temperature control a bit far, these unforeseen variables must still be accounted for and as such, there must be a solution for these problems. There is also a greater deal of control difficulties created by unknown disturbances. As such the usage of higher-order dynamics and can depict the description of the prescribed systems. Stability analysis is also a key factor in guaranteeing coverage for these converges. Introduction to parameters may significantly improve the performance of the system. However, these parameters may be the result of a large trial and error which may be time-consuming in the long run. As simulations can be a greater alternative to the improvement of performances of the tracking and disturbance rejection. This can deal with the robustness and disturbance rejection questions simultaneously because these systems can not only be applied to first-order systems but also another high order system.

For the included needed amount of work for each conclusion to take place the comparisons have to be made by keeping a smaller range of temperatures to simulate the smaller or more secluded aspects of the power ratios. However, the load variations and changes can also vary due to these possible consequences; As such designing prototypes to simulations may have to focus mainly on the variables before slinking into the testing of the possible other unknown variables that can sink into the system.

Going towards the electrification and automation of the present agricultural vehicles provides flexibility in control which results in its full automation capability. Many problems in the field of agriculture have been resolved because of this.

The fast-paced technological advancements will likely further improve these systems in the near future to give the farmers a better yield and a better experience in their job.

12. RECOMMENDATIONS

As stated in the conclusion, the recommendations are for the unseen variables to be taken care of or to be put into consideration before making any considerable judgment. Fuzzy logic on temperature can function solely on the output of the desired object and the natural temperature of the area, however taking into consideration the temperature control for the unforeseen variable. A greater deal of control difficulties will take place. These unforeseen variables or factors may create disturbances within the system that will not take place in a prescribed and simulated system. Usage of higher-order dynamics can vastly improve these circumstances however it may still lack the needed accurate output that must be done. As such occurrences of the stability must be a key factor in the determination of possible consequences and issues in the system. This is for the guarantee of coverage of these convergences.

Parameters may be a reasonable goal or idea for the creation of this system. However, parameters can result in trial and error even when simulated due to unforeseen problems and the number of factors for the system. One cannot avoid human error, as well as such simulations, maybe a better option in terms of testing the proposed control system. Tracking the robustness of the system may be dependent on the level of order system the fuzzy logic is on so the creation of possible consequences and stability must be taken into account to determine the factors of the trial and error. Designs and mathematical formulations are once taken into consideration can help in determining the maximum capacity of the fuzzy logic. The maximization of the truth table while looking for details and designing the fuzzy logic based on the actual location of construction must also be taken into consideration to create the most effective fuzzy logic there is for temperature and control system for the regulation of the temperature.

REFERENCES

[1] "Basic principles of fuzzy logic and neural networks," Practical Process Control for Engineers and Technicians. pp. 155–164, 2005. https://doi.org/10.1016/B978-075066400-4/50013-6

[2] R. Aguilar, V. Muoz, and Y. Callero, "Control Application Using Fuzzy Logic: Design of a Fuzzy Temperature Controller," Fuzzy Inference System - Theory and Applications. Sep. 2012. https://doi.org/10.5772/36212

[3] A. Africa, "A rough set-based data model for heart disease diagnostics." ARPN Journal of Engineering and Applied Sciences. Vol. 11, No. 15, pp. 9350-9357, 2016.

[4] L. Torrizo and A. Africa, "Next-hour electrical load forecasting using an artificial neural network: Applicability in the Philippines." International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 3, pp. 831-835, 2019. https://doi.org/10.30534/ijatcse/2019/77832019

[5] W. Lei, S. Hui, C. Ming-Yuan, Y. Hong, and W. Qiong, "The Simulation Study on Temperature Control System of Nitriding Electric-Furnace Based on Fuzzy-PID Control," 2009 First International Workshop on Education Technology and Computer Science, 2009.

[6] A. Africa, P. Arevalo, A. Publico, and M. Tan. "A comprehensive study of the functions and operations of control systems." International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 3, pp. 922-926, 2019. https://doi.org/10.30534/ijatcse/2019/89832019

[7] A. Africa, P. Arevalo, A. Publico, and M. Tan, "Linear system interconnections, steady-state analysis and stability theory." International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 4, pp. 1395-1398, 2019. https://doi.org/10.30534/ijatcse/2019/56842019

[8] C. Uy and A. Africa, "Development of a cost-efficient waste bin management system with mobile monitoring and tracking." International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 2, pp. 319-327, 2019. https://doi.org/10.30534/ijatcse/2019/35822019

[9] A. Jose and N. Cruz, "Climate change impacts and responses in the Philippines: water resources," Climate Research.Vol. 12, pp. 77–84, 1999.

[10] T. H. Kwan, X. Wu, and Q. Yao, "Complete implementation of the combined TEG-TEC temperature control and energy harvesting system," Control Engineering Practice. Vol. 95, p. 104224, 2020. https://doi.org/10.1016/j.conengprac.2019.104224

[11] E. Abiri and A. Darabi, "Reversible logic-based magnitude comparator (RMC) circuit using modified-GDI technique for motion detection applications in image processing," Microprocessors and Microsystems. Vol. 72, p. 102928, 2020.

[12] Y. Liu, C. Wu, Z. Min, and X. Zhang, "Control Logic Design Based on Modeling of Aircraft Cockpit Temperature Control System," Lecture Notes in Electrical Engineering Man–Machine–Environment System Engineering. Pp. 435–443, 2019. https://doi.org/10.1007/978-981-13-8779-1_50

[13] E. Magsino, K. Obias, J. Samarista, M. Say, and J. Tan "A redundant flight recovery system implementation during an octocopter failure," IEEE Region 10 Annual International Conference, Proceedings/TENCON, 2016.

[14] I.-J. Su, C.-C. Tsai, and W.-T. Sung, "Area temperature system monitoring and computing based on adaptive fuzzy logic in wireless sensor networks," Applied Soft Computing. Vol. 12, No. 5, pp. 1532–1541, 2012.

[15] J. Del Rosario, and E. Dadios, "Development of a fuzzy logic-based PV solar tracking system simulated using QT fuzzy engine," 2014 International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management, HNICEM 2014 - 7th HNICEM 2014 Joint

with 6th International Symposium on Computational Intelligence and Intelligent Informatics, co-located with 10th ERDT Conference, 2014. https://doi.org/10.1109/HNICEM.2014.7016232

[16] W. F. Godoy, I. N. D. Silva, A. Goedtel, and R. H. C. Palácios, "Fuzzy Logic Applied at Industrial Roasters in the Temperature Control," IFAC Proceedings Volumes.Vol. 46, No. 7, pp. 450–455, 2013.

[17] L.-H. Yang, B.-H. Huang, C.-Y. Hsu, and S.-L. Chen, "Performance analysis of an earth–air heat exchanger integrated into an agricultural irrigation system for a greenhouse environmental temperature-control system," Energy and Buildings. Vol. 202, p. 109381, 2019. https://doi.org/10.1016/j.enbuild.2019.109381

[18] H. Xu, Z. Zhang, H. Zhou, and Y. Bi, "Structural optimization and algorithm design for a temperature control system of a mid-infrared diode laser," Optik. p. 163854, 2019. https://doi.org/10.1016/j.ijleo.2019.163854

[19] Y. Yao, J. Wang, J. Zhang, and M. Yang, "Stability analysis on flow parameters in coolant temperature control system of a lead-cooled fast reactor," Annals of Nuclear Energy, 27-Nov-2018. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0306454918306327. [Accessed: 08-Dec-2019].

[20] R. Chi, Y. Lv, and B. Huang, "Distributed iterative learning temperature control for a multi-zone HVAC system," Journal of the Franklin Institute, 28-Oct-2019. [Online].Available: https://www.sciencedirect.com/science/article/pii/S0016003219307379. [Accessed: 08-Dec-2019].

[21] E. Abiri and A. Darabi, "Reversible logic-based magnitude comparator (RMC) circuit using the modified-GDI technique for motion detection applications in image processing," Microprocessors and Microsystems, vol. 72, p. 102928, 2020. https://doi.org/10.1016/j.micpro.2019.102928

[22] O. P. Verma and H. Gupta, "Fuzzy Logic Based Water Bath Temperature Control System." [Online]. Available: https://pdfs.semanticscholar.org/ea0f/27e9787d6525ebee13baf51ac0584767a654.pdf. [Accessed: 08-Dec-2019].

[23] C. Escolar-Jimenez, K. Matsuzaki, and R. Gustilo, "A neural-fuzzy network approach to employee performance evaluation." International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 3, pp 573-581, 2019. https://doi.org/10.30534/ijatcse/2019/37832019

[24] C. Escolar-Jimenez, K. Matsuzaki, and R. Gustilo, "Intelligent shortlisting process for job applicants using fuzzy logic-based profiling." International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 3, pp 567-572, 2019. https://doi.org/10.30534/ijatcse/2019/36832019

[25] A. Africa, G. Ching, K. Go, R. Evidente, and J. Uy, "A comprehensive study on application development software systems." International Journal of Emerging Trends in Engineering Research. Vol. 7, No. 8, pp 99-103, 2019. https://doi.org/10.30534/ijeter/2019/03782019

[26] A. Africa, F. Espiritu, C. Lontoc, and R. Mendez, "The integration of computer systems into the expansive field of video games." International Journal of Advanced Trends in Computer Science and Engineering. Vol. 8, No. 4, pp 1139-1145, 2019. https://doi.org/10.30534/ijatcse/2019/22842019

[27] A. Africa, T. Dolores, M. Lim, L. Miguel, and V. Sayoc. "Understanding logical reasoning through computer systems." International Journal of Emerging Trends in Engineering Research. Vol. 8, No. 4, pp 1187-1191, 2020.