

CHAPTER: 04

FUZZY SET THEORY EMPOWERING MACHINES: APPLICATIONS IN ARTIFICIAL INTELLIGENCE AND ROBOTICS

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ABSTRACT

This review of the literature related to fuzzy set proposition has been developed with special emphasis on how fuzzy set and fuzzy logic has advanced in a variety of ways in numerous disciplines. The objective to this paper is to bring together the applications of fuzzy set theory and fuzzy logic in artificial intelligence and robotics. Necessary flow charts have been used to explain the procedures. The review intends to delve into a comparative analysis between the fuzzy set theory and other approaches, which helps to simplify that fuzzy logic has the ability to handle uncertain and imprecise data, making it highly effective choice in cases where strict categorization may not be sufficient.

Keywords:- Fuzzy set theory, fuzzy logic, artificial intelligence, robotics

1) INTRODUCTION

Fuzzy set theory is a mathematical framework introduced by Lotfi A. Zadeh in 1965, which expands classical set proposition to manage query and vagueness in a more flexible way. Contrasting the classical set or crisp set, where element either belongs or does not belongs to the set, fuzzy set allows for partial membership. The degree of membership is represented between 0 and 1 [41][46]. Fuzzy set theory has found widespread application in various fields, including artificial intelligence, data mining, medical diagnosis, robotics and environmental engineering[48]. This mathematical formalism has proven to be instrumental in addressing complex problems where precise boundaries and categorizations may be challenging to define. As a result, fuzzy set theory has become an essential component in the development of systems and algorithms that can better mimic human reasoning and decision-making processes, contributing to advancements in diverse fields and offering a more realistic representation of uncertainty in the modeling of complex systems [50]. Fuzzy logic play a very important role as it can be used for the growth of

intelligent structure for decision-making, identification, pattern remembrance, etc. In many engineering and scientific fields application of fuzzy logic have been appreciated. In many applications such as washing machines, vacuum cleaner, rice cooker, air conditioner, cars, etc. fuzzy logic has been used [42][47]. In order to make any appliance work using fuzzy logic the basic algorithm that is used is : fuzzification, rule or inference and defuzzification[43]. Fuzzy logic has many applications in embedded control applications which show how the design cycle becomes short using the method and also the logic problems are solved which weren't possible to break by traditional direct method [44].

In an effort to gain better understanding of the fuzzy set theory and to provide a basis for future research, a literature review of fuzzy set theory empowering machine has been conducted in this paper.

In the subsequent sections, the methodology of fuzzy set theory in artificial intelligence and robotics is discussed and then the applications of Fuzzy logic in some machines. Further a comparative analysis of fuzzy set theory against other approaches in specific applications is discussed.

2) METHODOLOGY OF FUZZY SET THEORY

- I) **Artificial Intelligence:** - In the evolving world of artificial intelligence, fuzzy set theory helps computers to form opinions in ambiguous situations [48]. For example a situation where it's not just a 'yes' or 'no' answer, but somewhere in between. The process begins by fluently understanding the problem. Rather than solely counting on numerical data, fuzzy set enable us to describe outcome using words like 'high' or 'low'. Fuzzy sets come into play by letting us talk about things that are not exactly one way or another, using a range of possibilities. By emulating the decision-making process of humans, artificial intelligence becomes more adaptable and smarter in tackling complex real-world situations. Hybrid models integrating fuzzy logic contributes to decision-making. AI method like neural network have been explored for improved accuracy.
- II) **Robotics:** - The methodology used in Robotics with the help of principles of fuzzy set theory presents robots equipped with fuzzy logic which gives it a flexible thinking approach. It incorporate the robots to do with complex and dynamic terrain. This approach helps robots to make decision based on degree of certainty, similar to how humans do. Fuzzy logic allows robot to navigate through changing terrains and making real-time adjustment. This adaptability enhances decision making skill of robots and hence improves its effectiveness in real world situation [42].

3) APPLICATION OF FUZZY SET THEORY (FUZZY LOGIC)

- I) **Washing Machine:-** Fuzzy logic, in case of a washing machine, employs sensors to check different conditions inside the machine and adjusts its operations consequently. The sensor in the washing machine controls the entire washing process performing operations according to different water input, wash time, rinse performance and spin speed.[5].

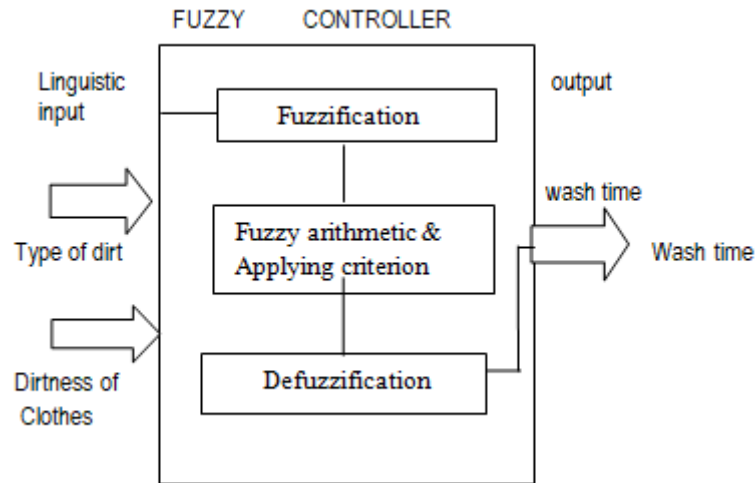


Fig 1:- The mechanism of Washing Machine.

Fuzzy logic controller helps the washing machine to automatically generate input and get the desired output, making it a smart washing machine which in comparison with the regular washing which is prone to breakage due to start-stop mechanism[1][10]. The medium is grounded on fuzzy inference system which is used in washing machine to get an appropriate wash, rinse, and spin time for different types and quantity of clothes and amount of dirtiness and the simulation was done by using fuzzy logic toolbox [2][4]. With the help of fuzzy logic the time taken (wash time) and the electricity consumption and water used for washing clothes in machine can be minimized [3][6]. In order to show that the washing machine provides a good washing quality, using fuzzy propositions control system, inputs like types of clothes, degree of dirt and mass of the cloth put into the machine and for the output as wash time, RPM, dry time and temperature [8]. It can also be shown how different clothes take a suitable washing time, based on the principle of taking approximate data from the detector, which uses the fuzzy arithmetic and achieves crisp values of the washing time [9].

Ref I) Washing Machine

- 1) R.F. Masood, "Application of fuzzy Logic in design of smart washing machine", Computer Science. System and Control, arXiv preprint arXiv: 1701.01654, 2017.
- 2) A.Fadel, M. Mhereeg, M. Shlibek, "Fuzzy logic based control system for intelligent washing machines", European Journal of Engineering Science and Technology 2 (4), 79-88, 2019.
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- II) **Vacuum Cleaner:-** Fuzzy logic controlled motor of vacuum cleaner. The vacuum cleaner regulator has one input and one output system.[15] The input is a distance which is two set of infrared detectors are used to detect the range of the dust and the output is the speed of the motor to absorb the dust. Formerly it starts the operation the vacuum cleanser will start to absorb dust and attempts to adjust the speed by comparing the distance. The algorithm of fuzzy logic and PIC controller are use to control the operation of the vacuum.

Fig 2:- The mechanism of Vacuum Cleaner.

The use of fuzzy logic navigator and control design for a non-holonomic robotic vacuum cleaner has been designed by Motorola flash microcontroller used to make the surrounding space clean. This algorithm helps the robot clean the area while avoiding any accident [13]. With the help of a robot vacuum cleaner the recovery rate of waste products is improved[15]. For a fuzzy control of a vacuum cleanser using a rule base reduction and tuning algorithm deals with the inconsistencies and redundancies stages are gradationally removed from the fuzzy rule without impacting the net performance of the regulator [11][12]. A wall cleaning robot that is used for building maintenance sector, with the help of vacuum suction this work becomes comparatively easy. Fuzzy logic plays an important role to produce a controlling criterion for a wall cleaning robot to make sure its safely and reliability and efficiency [16].

Ref. II) Vacuum Cleaner

- 11) M Kemal Ciliz, "Rule base reduction for knowledge based fuzzy controllers with application to a vacuum cleaner", Expert Systems with Application 28(1), 175-184, 2005.
- 12) M Kemal Ciliz, "An advanced tuning methodology for fuzzy control: with application to a vacuum cleaner", Proceedings of 2003 IEEE Conference on Control Applications, 2003. CCA 2003. 1, 257-262, 2003.
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- 16) MA Viraj J Muthugala, Manuel Vega-Heredia, Rajesh Elara Mohan, Suresh Raj Vishaal, "Design and control of a wall cleaning robot with adhesion-awareness", Symmetry 12(1),122,2020.

- III) **Rice Cooker:-** Neuro-Fuzzy Heat Adjuster Fine-tuned heat adjustment. Three detectors help the neuro-fuzzy make the precise choice.[23]

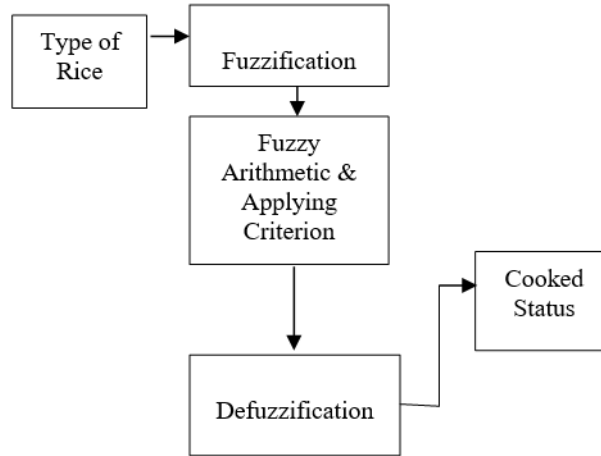


Fig 3:- The mechanism of Rice cooker

By use of Fuzzy logic control, the time required for cooking rice based on the types of rice can be controlled. By this method a suitable cooking time for different types of rice is achieved, which further ensures to automate the rice cooker [21][29]. The use of Fuzzy logic controller system in rice cooking while evaluating the performance of two algorithms MATLAB Fuzzy logic toolbox and fuzzyTECH software [22][27]. The Fuzzy logic controller (FLC) also proposes an automatic rice cooker temperature controller, where the temperature is supposed with the difference between the total time required and the quantity of rice [23][28]. Fuzzy logic Mamdani method can be used to assume the quantity of national rice that must be produced applying the four parameters :- production , availability, demand and distribution [24].

Ref III) Rice Cooker

- 17) M.C. Pradhan, S.Satpathy , B.K. Bhoi, "An intelligent fuzzy based technique of making food using Rice cooker", Asian Journal of Electrical Sciences 5(1), 1-7, 2016.
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- 23) N Deborah Lynn, Al Sourav, AJ Santoso, "A fuzzy logic-based control system for microwave opens", Journal of Physics: Conference Series 1577(1), 012021, 2020.

- 24) R.Aisuwarya, Y.Vidiana, "Smart Rice cooker with PID Method to warm food using android application", 3rd International Conference on Mechanical, Electronics, Computer and industrial Technology (MECnIT), 261-266,2020.
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IV) Cars: - Fuzzy sets find Precious operations in auto systems, particularly in enhancing decision- making processes. In the environment of independent vehicles, fuzzy sense can be employed to handle uncertain or squishy data, similar as nebulous detector inputs or changeable road conditions[38]. By using fuzzy set proposition, these systems can adaptively acclimate parameters like speed, steering, and retardation, allowing for further nuanced and environment- apprehensive responses. This approach aids in creating intelligent and responsive automotive systems able of navigating different and dynamic surroundings with advanced safety and effectiveness.

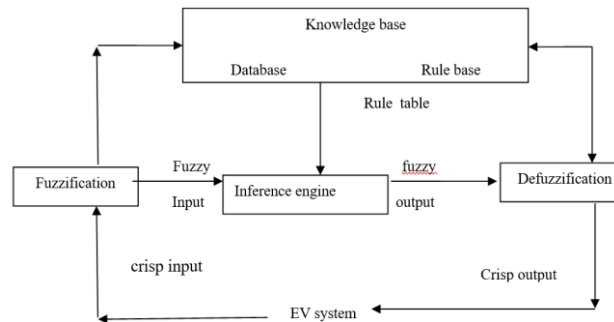


Fig 4:- The mechanism of car.

Use of fuzzy logic controller, the vehicle model that has five degree of freedom with a passenger seat, supplies the stylish lift comfort [38]. The artificial neural networks and fuzzy propositions are veritably useful to the vehicle dynamics and control [36]. With the help of FLC, the increasing rate of road accident can be reduced by developing the automatic brake system and also prevent wheel lock and collision with an obstacle, which can be detected by ultrasonic sensors. Fuzzy propositions rules can be used for both discovery and antilock retardation system [35]. Fuzzy logic algorithm helps to cover modern vehicles from cyber attacks. The lack of security of the controller area network can make the vehicles at risk to attack[34].The fuzzy logic controller is used the improve the performance of modern cars with the applications:- engine idle speed, automatic transmission , cruise controller, anti-knock control system [33]. Fuzzy Interference system can also be used for designing the traffic flow modeling to predict the future behavior of the Driver Vehicle Unit (DVU) which can be used in driver assistance devices, safe distance, prevention of collision and other intelligent transportation system [32]. FLC has been studied and used in vehicles from a very long period of time which is classified in the intelligent control system and is capable of dealing with the system containing non-linearity and uncertainty [31].

Ref (IV) Car

- 27) E. Uzunsoy, "A brief review on fuzzy logic used in vehicle dynamics control", Journal of Innovation Science and Engineering (JISE) 2(1), 1-7, 2018.
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- 36) ML Devdutt, "Fuzzy logic control of a semi-active quarter car system", *Int. J. Mech. Ind. Sci. Eng* 8, 163-167, 2014.

4) COMPARATIVE ANALYSIS

Fuzzy set theory in comparison to other approaches in specified applications, many factors come into play.

To illustrate

- In control system, if we use the conventional crisp logic which can only provide precise rules but may have to give more efforts in managing the uncertainties as compared to fuzzy logic which is more flexible to the dynamic environment.
- In medical diagnosis, probabilistic model off statistical insights whereas fuzzy logic adjusts imprecise symptoms very effectively.
- In data mining the use of fuzzy logic proves to be a challenging tool in handling complex datasets, which provides a comprehensive understanding of complex pattern that may otherwise be difficult to discern using traditional crisp set.
- In robotics, the crisp control logic may struggle to adapt, fuzzy logic allows for real-time modifications in unstable environment.
- When considering which method to use, the decision between fuzzy set theory and other approaches is heavily influenced by the specific needs of the application. What sets fuzzy logic apart is its ability to handle uncertain and imprecise data, making it a highly effective choice in cases where strict categorization may not be sufficient.

5) CONCLUSION

This paper has been discussed as a literature review on fuzzy set theory applications across diverse fields. Throughout the course of this study, it has been observed that in various field what is the methodology of using fuzzy set theory and fuzzy logic. The applicableness and contribution of fuzzy set theory are discussed in the operation section[42] in which it has big impact. Thereafter providing a comparative analysis of fuzzy set theory against other approaches. From the discussion of the above it is concluded the fuzzy set theory[50] stands as a valuable tool for managing the uncertainties inherent in diverse fields, by actively participating, we can improve the precision and versatility of our solution when faced with uncertain information.

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