# Methodology for an Expert System by Utilization of Fuzzy Logic Algorithms

Om Awasthi[1], Mr. Arun Rai[2]
*Vedica Institute of Technology, RKDF University, Bhopal*
[2]raiarun89@gmail.com

*Abstract) — The fuzzy logic system in washing machines relies on the detection of four key input parameters: the amount of dirt, the type of dirt, the sensitivity of the garment's material, and the number of items being washed. Based on these inputs, the system determines the optimal washing speed, time, water temperature, and detergent amount. Utilizing fuzzy logic rules simplifies the process of achieving cleaner laundry compared to traditional methods that require manual adjustments. Furthermore, fuzzy logic contributes to more efficient use of water, detergent, and electricity, ultimately saving time and reducing overall costs. This paper reviews existing literature to examine the impact of fuzzy logic in enhancing washing machine control systems. The output are the wash time which are obtained by the defuzzification of fuzzy set values. So by the recommended work we are able to identify what should be the efficient wash time when such conditions like very hard water, dirtiness are more, type of dirt are very greasy & mass of cloth are heavy in a controller of a washing machine for washing the clothes .In this chapter we have explained our recommended work by taking the suitable example & also drawing the flow diagram how & from where the data flows into the system ,we have utilized mamdani FIS to design our load balancing fuzzy logic algorithm. We have implement our recommended work in MatLab Fuzzy logic tool.*

Keywords — *Washing machine system; Fuzzy logic algorithms; Matlab*

## I. Introduction

Lotfi A. Zadeh from the University of California, Berkeley, introduced fuzzy logic in 1965. The primary motivation for implementing fuzzy logic is to effectively manage non-linear systems that are otherwise difficult to control. By employing fuzzy logic and fuzzy set theory, we can address uncertainty and probability. Fuzzy logic represents a unique approach to control and classification issues, emphasizing the intended outcomes of the system rather than the underlying mechanics. This allows for a focus on problem-solving rather than precise quantitative modeling when feasible. However, developing a fuzzy logic system necessitates considerable expertise in formulating the rule base, combining sets, and defuzzification. Overall, fuzzy logic is exceptionally beneficial for intricate processes lacking clear mathematical models or where expert knowledge is represented linguistically. The goal of this article is to apply fuzzy logic to the functioning of washing machines, which are essential household appliances today. A washing machine that effectively manages wash duration is vital for ensuring optimal performance. The greatest advantage for users is the machine's ability to automate the tasks of scrubbing, agitating, and washing garments. As a result, fuzzy logic washing machines are becoming increasingly popular.

The focus of this paper is to introduce a reward system that emphasizes appearance, productivity, and simplicity instead of just price. Due to the lack of a standardized approach to fuzzy logic, each machine operates differently. This study aims to recommend a method for governing washing durations through fuzzy logic control, illustrating how to determine the appropriate washing time for various fabrics. The proposed approach accounts for imprecise sensor inputs, processes them through fuzzy sums, and ultimately produces a precise washing time. The paper highlights that this method can be effectively implemented in practice to further enhance washing machine automation.

Moreover, the appeal of a washing machine utilizing fuzzy logic lies in its collaborative features, simplicity, efficiency, and affordability. Such machines regularly adjust to changing conditions via sensors, optimizing operations to achieve superior washing results. Given the absence of a universal model for fuzzy logic, the performance of different machines can vary. Typically, fuzzy logic governs aspects of the washing process, including water intake, temperature, washing duration, rinse cycles, and spin speed, all contributing to a longer lifespan for the machine.

## II. APPLICATION OF FUZZY LOGIC

Fuzzy logic finds application across numerous fields, including electrical, mechanical, civil, chemical, aerospace, agricultural, biomedical, computer, environmental, geological, commercial, and mechatronic engineering; as well as mathematics, software development, natural sciences (biology, chemistry, earth science, and physics), and social sciences (economics, management, political science, and psychology). It has been successfully used in a wide array of applications, such as facial recognition systems, air conditioners, washing machines, vacuum cleaners, anti-skid braking systems, transmission systems, subway control systems, unmanned aerial vehicles, multi-objective optimization for power systems, weather forecasting systems, and design models for new automobiles. Fuzzy logic has demonstrated its effectiveness in fields that include control systems engineering, image processing, energy management, industrial automation, robotics, and maintenance services.

## III. LITERATURE REVIEW

### *A. Fuzzy Logic*

In 1965, Professor Lotfi A. Zadeh from the University of California introduced the concept of fuzzy logic. This approach has become a valuable design framework for developing and articulating control systems, empowering engineers with an intuitive method to construct complex systems, known as fuzzy logic systems. By allowing for the simultaneous alteration of multiple states, engineers can more effectively describe system behavior and manage inputs.

Fuzzy logic is prevalent in two main forms: neural networks and rule-based systems. Both applications have extensive uses across various fields such as security, medicine, avionics, and machine learning. Rule-based systems leverage expertise, encoding thought processes and rules directly into the system. Unlike neural networks, these systems do not require extensive training datasets. In contrast, neural networks typically rely on just two datasets for programming—the trainer and another set of inputs. The neural network processes these inputs, storing values in arrays referred to as nodes, where each node contains specific information alongside data distributed among its neighboring nodes. Once all data has been processed, it is analyzed, saved as a template, and cross-referenced with other datasets. Rule-based fuzzy logic systems offer the advantage of clearer justifications for user behavior, as their actions are driven by defined parameters or rules, where any changes in these parameters indicate a motivation to act.

### *B. Fuzzy Control of Washing Machines*

In the past, users had to manually select the laundry type on washing machines, entering the amount of water and washing time before starting the cycle. Today's automatic washing machines utilize fuzzy logic to streamline this process. This innovation represents a significant leap forward, particularly in water conservation. Fuzzy control systems can assess various factors and determine the optimal cleaning settings. By evaluating the washing parameters, the weight of the load, and the levels of dirt, water, and power needed, fuzzy control ensures that washing machines operate efficiently and effectively.

### *C. Related Work*

Initially, the use of fuzzy logic was primarily confined to control systems and process control, as the mathematical modeling of planetary systems was not well understood. However, over time, fuzzy control has expanded its applications across various fields, each with unique complexities and performance goals. For instance, in Zhen's work, a fuzzy controller for a washing system, which integrates fuzzy logic with neural networks and their learning algorithms, has been extensively investigated. The backpropagation (BP) neural network is integrated with fuzzy control, with simulations conducted using MATLAB. Key parameters such as bathing time, water level, and waft depth are pre-set. To adjust limitations, fuzzy rules are employed, generating characteristics automatically. These parameters can be modified in real-time, enhancing overall washing machine efficiency while maximizing water and energy savings [12].

In a separate study by Gui-juan et al., a fuzzy controller based on a self-organizing framework was developed using the L-M algorithm for the BP network. This setup, simulated in MATLAB, showed that the neuro-fuzzy controller was effectively trained for managing the washing process. Comparative simulations confirmed the practicality of the control system [13].

Furthermore, Kaler et al. proposed a fuzzy inference system (FIS) that assesses the cleanliness of laundry by considering inputs like washing powder, duration, and water temperature. The output of the FIS is validated against real results to ensure quality. An adaptive fuzzy inference approach, employing a neural network, was also introduced to evaluate clothing cleanliness using the same input data and comparing with actual output. Each outcome is verified to ensure accuracy, suggesting that such controllers could significantly enhance the performance and reliability of washing machines. These solutions were crafted utilizing the FIS and ANFIS toolboxes in MATLAB [14].

Zhen Y. et al. elaborated on fuzzy control as an intelligent control strategy rooted in fuzzy set theory, fuzzy variables, and logical deduction. Their research focused on washing machines as the control object, detailing the fuzzy decision-making process, analyzing the control theory with three inputs and two outputs, and developing fuzzy rules before illustrating the fuzzy control decisions and simulation outcomes [15].

## IV. METHODOLOGY

The recommended technique of designing the fuzzy logic based control system consist of 27 rules that are made by the mapping of input variables to the output data. By theutilization of membership function the input values are converted into fuzzy sets.

Rule 1

If (Type of Dirt are Greasy) or (Turbidity of Cloth are Large) or (Mass of Cloth are Heavy) or (Sensitivity of Cloth are More Sensitive) or (Water Hardness are Hard) then (Wash Time are Long)(Wash Speed are Medium)(Amount of Water are Normal)(Amount of Detergent are Normal)(Water Hotness are Medium)

Rule 2

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are Not Sensitive) & (Water Hardness are Soft) then (Wash Time are Very Short)(Wash Speed are Very Short)(Amount of Water are Less)(Amount of Detergent are Less)(Water Hotness are Low)

Rule 3

If (Type of Dirt are Less Greasy) & (Turbidity of Cloth are Medium) & (Mass of Cloth are Medium) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Moderate) then (Wash Time are Medium)(Wash Speed are Medium)(Amount of Water are Normal)(Amount of Detergent are Normal)(Water Hotness are Medium)

Rule 4

If (Type of Dirt are Not Greasy) or (Turbidity of Cloths Small) or (Mass of Cloth are Light) or (Sensitivity of Cloth are Not Sensitive) or (Water Hardness are Soft) then (Wash Time are Short)(Wash Speed are Medium)(Amount of Water are Normal)(Amount of Detergent are Normal)(Water Hotness are Low)

Rule 5

If (Type of Dirt are Greasy) & (Turbidity of Cloths Large) & (Mass of Cloth are Heavy) & (Sensitivity of Cloth are More Sensitive) & (Water Hardness are Hard) then (Wash Time are Very Long)(Wash Speed are Very Long)(Amount of Water are More)(Amount of Detergent are More)(Water Hotness are High)

Rule 6

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are Not Sensitive) & (Water Hardness are Moderate) then (Wash Time are Very Short)(Wash Speed are Very Short)(Amount of Water are Less)(Amount of Detergent are Less)(Water Hotness are Low)

Rule 7

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are Not Sensitive) & (Water Hardness are Hard) then (Wash Time are Very Short)(Wash Speed are Short)(Amount of Water are Less)(Amount of Detergent are Less)(Water Hotness are Low)

Rule 8

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Soft) then (Wash Time are Very Short)(Wash Speed are Very Short)(Amount of Water are Less)(Amount of Detergent are Less)(Water Hotness are Low)

Rule 9

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Moderate) then (Wash Time are Very Short)(Wash Speed are Very Short)(Amount of Water are Less)(Amount of Detergent are Less)(Water Hotness are Low)

Rule 10

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Hard) then (Wash Time are Short)(Wash Speed are Short)(Amount of Water are Less)(Amount of Detergent are Less)(Water Hotness are Low)

Rule 11

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are More Sensitive) & (Water Hardness are Soft) then (Wash Time are Very Short)(Wash Speed are Very Short)(Amount of Water are Less)(Amount of Detergent are Less)(Water Hotness are Low)

Rule 12

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are More Sensitive) & (Water Hardness are Moderate) then (Wash Time are Short)(Wash Speed are Short)(Amount of Water are Less)(Amount of Detergent are Less)(Water Hotness are Low)

Rule 13

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are More Sensitive) & (Water Hardness are Hard) then (Wash Time are Short)(Wash Speed are Medium)(Amount of Water are Less)(Amount of Detergent are Normal)(Water Hotness are Medium)

Rule 14

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Medium) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Soft) then (Wash Time are Short)(Wash Speed are Medium)(Amount of Water are Less)(Amount of Detergent are Normal)(Water Hotness are Medium)

Rule 15

If (Type of Dirt are Not Greasy) & (Turbidity of Cloth are Medium) & (Mass of Cloth are Medium) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Moderate) then (Wash Time are Medium)(Wash Speed are Long)(Amount of Water are Normal)(Amount of Detergent are Normal)(Water Hotness are Medium)

Rule 16

If (Type of Dirt are Less Greasy) & (Turbidity of Cloth are Medium) & (Mass of Cloth are Medium) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Moderate) then (Wash Time are Medium)(Wash Speed are Long)(Amount of Water are Normal)(Amount of Detergent are Normal)(Water Hotness are Medium)

Rule 17

If (Type of Dirt are Less Greasy) & (Turbidity of Cloth are Medium) & (Mass of Cloth are Heavy) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Moderate) then (Wash Time are Long)(Wash Speed are Long)(Amount of Water are More)(Amount of Detergent are More)(Water Hotness are High)

Rule 18

If (Type of Dirt are Greasy) & (Turbidity of Cloth are Medium) & (Mass of Cloth are Medium) & (Sensitivity of Cloth are More Sensitive) & (Water Hardness are Hard) then (Wash Time are Long)(Wash Speed are Long)(Amount of Water are More)(Amount of Detergent are More)(Water Hotness are High)

Rule 19

If (Type of Dirt are Greasy) & (Turbidity of Cloth are Medium) & (Mass of Cloth are Heavy) & (Sensitivity of Cloth are More Sensitive) & (Water Hardness are Hard) then (Wash Time are Very Long)(Wash Speed are Long)(Amount of Water are More)(Amount of Detergent are More)(Water Hotness are High)

Rule 20

If (Type of Dirt are Greasy) & (Turbidity of Cloth are Large) & (Mass of Cloth are Medium) & (Sensitivity of Cloth are More Sensitive) & (Water Hardness are Hard) then (Wash Time are Very Long)(Wash Speed are Very Long)(Amount of Water are More)(Amount of Detergent are More)(Water Hotness are High)

Rule 21

If (Type of Dirt are Less Greasy) & (Turbidity of Cloth are Large) & (Mass of Cloth are Medium) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Moderate) then (Wash Time are Long)(Wash Speed are Long)(Amount of Water are More)(Amount of Detergent are More)(Water Hotness are High)

Rule 22

If (Type of Dirt are Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Heavy) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Hard) then (Wash Time are Long)(Wash Speed are Long)(Amount of Water are More)(Amount of Detergent are More)(Water Hotness are High)

Rule 23

If (Type of Dirt are Greasy) & (Turbidity of Cloth are Large) & (Mass of Cloth are Light) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Hard) then (Wash Time are Long)(Wash Speed are Long)(Amount of Water are Normal)(Amount of Detergent are More)(Water Hotness are High)

Rule 24

If (Type of Dirt are Greasy) & (Turbidity of Cloth are Large) & (Mass of Cloth are Heavy) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Soft) then (Wash Time are Long)(Wash Speed are Long)(Amount of Water are Normal)(Amount of Detergent are More)(Water Hotness are High)

Rule 25

If (Type of Dirt are Less Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Light) & (Sensitivity of Cloth are Not Sensitive) & (Water Hardness are Moderate) then (Wash Time are Very Short)(Wash Speed are Very Short)(Amount of Water are Less)(Amount of Detergent are Less)(Water Hotness are Low)

Rule 26

If (Type of Dirt are Less Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Medium) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Moderate) then (Wash Time are Short)(Wash Speed are Medium)(Amount of Water

are Normal)(Amount of Detergent are Normal)(Water Hotness are Low)
Rule 27

If (Type of Dirt are Less Greasy) & (Turbidity of Cloth are Small) & (Mass of Cloth are Heavy) & (Sensitivity of Cloth are Less Sensitive) & (Water Hardness are Moderate) then (Wash Time are Medium)(Wash Speed are Long)(Amount of Water are Normal)(Amount of Detergent are Normal)(Water Hotness are Medium)

The Comparison graph are shown in figure 6.13 . The fuzzy logic basedcntroller propsed by Pritesh lohani gives the output as a Wash time of 30.36 minutes. They have consider 3 input parametrs as Type of dirt, Dirtiness of cloths & mass of cloths. The Manish agarwal recommended a controller with input variables as Type of dirt, Degree of dirt & the Wash time as an output of 38.15 minutes. Hatager & Halase recommended the control system of 3 input varaiables of Type of dirt, Dirtiness of cloths & mass of cloths nad the output are the Wash time of 42.3 minutes. We have recommended DFWM Controller by 5 input parameters of Type of dirt, Turbidity of cloths & mass of cloths, Sensitivity of cloths & Water hardness. The output obtained are Wash time of 25.3 minutes.

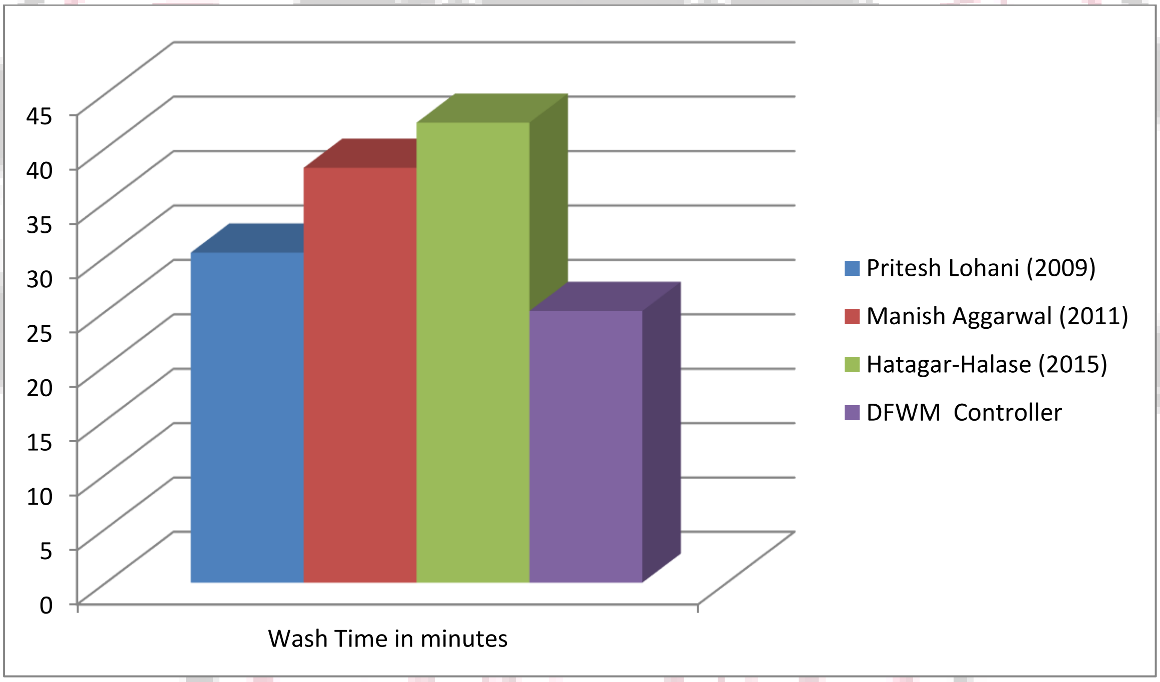


**Figure 1: Result comparison with different authors**

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**Table 1 Comparison of DFWM result with base paper result**

| Sno | Base Paper | DFWM |
|---|---|---|
| 1 | The wash Time are obtained are of 42.3 minutes. | The wash Time are obtained are of 25.3 minutes. |
| 2 | They consider 3 input paarametrs: Type of Dirt Dirtiness of cloths Mass of cloths | We consider 5 input paramets: a)Type of Dirt b)Turbidity of cloths c) Mass of cloths d) Sensitivity of cloths e) Water Hardness |
| 3 | They have developed 27 rulles with 3 input parametrs. | We have developed optimized 27 rules with 5 input variables. |
| 4 | They does not consider the impact of wash time for type of cloth & water hardness. | We have shown the wash time are affected the type of cloths & hardness of water |
| 5 | The obtained output are Wash Time. | The output obtained as: a)Wash Time b) Wash Speed c) Amount of water d) Amount of detergent |

The table 1 are shown above describes the comparison of recommended controller result with the base paper result which was developed by Sudha Hatagar & Halase. In this table we have compare our result with the base paper & showed that our average wash time obtained are much more efficient than that of the base paper one.

## V. Conclusion

In light of the findings from this study, this paper emphasizes the implementation of a washing machine system that optimally utilizes various parameters. The washing speed, duration, hot water temperature, and detergent quantity are all tailored based on specific inputs. Compared to the previous method of manually adjusting settings, the adoption of fuzzy logic principles streamlines the process of achieving cleaner laundry. Additionally, fuzzy logic not only conserves water, detergent, and energy but also saves valuable time, significantly reducing overall operational costs. This project seeks to design and implement an advanced washing machine system while exploring the impact of fuzzy logic on its control mechanisms.

This paper conducts a thorough review of existing literature to evaluate how fuzzy logic rules can enhance washing machine control systems. The fuzzy logic framework for washing machines is founded on the detection of four key input parameters: the amount and type of dirt, the material sensitivity, and the number of garments. Consequently, washing speed, time, hot water temperature, and detergent quantity are dynamically adjusted based on these inputs. Utilizing fuzzy logic makes obtaining cleaner laundry easier than relying on traditional manual adjustments. Moreover, the introduction of fuzzy logic contributes to significant savings in water, detergent, and electricity, along with considerable time savings, ultimately leading to reduced operational costs.

The recommended fuzzy logic based load balancing algorithm are designed by considering five input parameters which produces five output parameters we determine membership functions for each variable for our fuzzy system & their corresponding fuzzy memberships These input variables are converted into fuzzy values through theutilization of Membership function which can be triangular, trapezoidal or Gaussian. So the recommended technique consist of three steps Fuzzification rule evaluation & Defuzzification. Fuzzification are the first step involved in recommended fuzzy logic controller in Fuzzification the transformation of crisp sets of values into fuzzy values occur then the second step are the rule determination We have recommended optimized 27 rules based on the mapping of the input & output parameters. The last step are the defuzzification it are the reverse process of fuzzification the conversion of fuzzy values into the crisp values. Then the output are the wash time which are obtained by the defuzzification of fuzzy set values . So by the recommended work we are able to identify what should be the efficient wash time when such conditions like very hard water, dirtiness are more, type of dirt are very greasy & mass of cloth are heavy in a controller of a washing machine for washing the clothes

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