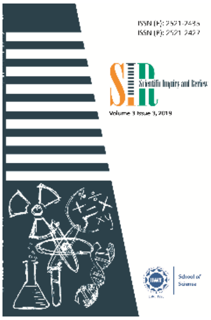

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Fuzzy Logic Controller: The Impact of Water pH on Detergents

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Abstract

In this research paper, the impact of water pH on detergent was measured by constructing a Fuzzy Logic Controller (FLC) based on Intuitionistic Fuzzy Numbers (IFNs) by incorporating three linguistic inputs and one output as taken by Saeed. M. *et al.* [1]. The inference process was carried out using MATLAB fuzzy logic toolbox and the results were compared with FLC based on fuzzy numbers. The objective of the study was the comparison of FLC based on intuitionistic and fuzzy numbers. The results showed that FLC based on IFNs is approximately the same but has more precise values. So, IFNs based FLC can be used in the Instinctive Laundry System.

Keywords: Fuzzy Numbers (FNs), Fuzzy Logic Controller (FLC), Intuitionistic Fuzzy Numbers (IFN's), MATLAB, instinctive laundry system

Introduction

The hypothesis of fuzzy sets has turned into a dynamic zone of research in various orders, including restorative, life science, the board science, sociology, decision-making, building, measurements, signal procedure, mechanical technology master framework, basic leadership, and multi-operator framework. Zadeh [2] presented the idea of fuzzy sets as a technique for addressing vulnerability and dubiousness. Fuzzy controllers are accustomed to controlling purchaser items, for example cameras, clothes washers, microwaves, concrete furnaces and robots. The most utilized FLC is the purported Mamdani [3] induction framework. In 2012, Ion Iancu [4] made the point by gathering significant data about Mamdani type Fuzzy Logic Controller (FLC). He presented the complete strides of FLC, that is, fuzzification, rules assessment, collection of the guideline yields and defuzzification. Cameron [5] talked about the use of cleanser for washing in hard water. He uncovered that how much additional cleanser in a powdered structure should work similarly to that of cleanser in fluid structure for washing in hard water. The pH impact on wash time in the programmed clothes washer was investigated by Saqlain. M. et al. [6]. Akram [7] proposed a plan for a programmed clothes washer having just two info and one yield, the wash time is acquired by utilizing defuzzification strategies.

In 1983, Atanassov [8] presented the idea of intuitionistic fuzzy sets as speculation of fuzzy sets. He incorporated in the meaning of fuzzy set another segment that decides the level of non-enrollment. Agarwal et. al. [9] introduced the structure of a probabilistic intuitionistic fuzzy principle-based controller. Akram et al. [10] described intuitionistic fuzzy rationale control for warmer fans. Saeed. M. et al. [1] exhibited the effect of pH on cleanser in a programmed clothes washer dependent on FLC.

Moreover, in this paper, we have set up the intuitionistic fuzzy rationale controller for a programmed clothes washer based on the intuitionistic fuzzy framework. Intuitionistic fuzzy surmising framework and defuzzification procedures are utilized to acquire fresh output (detergent) from an IFN as information (fabric type, soil type, water-pH). FLC based IFNs are used to make washing machines more automatic as compared to FLC results, which increases consumer satisfaction. This problem can also be observed in terms of MCDM and applications that are not mentioned in the paper, the readers can refer to [12, 13, 14, 15, 16, 17, 18].

Riaz. M et al. [11] discussed the effect of water types and temperature in automatic washing machines. They concluded that soft water and high temperature should be used in washing machines for reducing the quantity of detergent. In this paper, some phonetic outcomes are achieved by applying FLC to IFNs.

2. Preliminaries

2.1 Definition

Let U be a universe of discourse. Then, the intuitionistic fuzzy set A is an object having the form $A = \{< x, \mu_A(x), v_A(x) >, x \in U\}$, where the function μ_A (x), v_A (x): U ⟶ [0, 1] defines the degree of membership and the degree of non-membership of the element $x \in X$ to the set A with the condition

$$0 \leq \mu_A(x) + v_A(x) \leq 1$$

2.2 Definition

For two intuitionistic fuzzy sets

$$A = \{< x, \mu_A (x), \nu_A (x) >, x \in X\} \quad and \quad B = \{< x, \mu_B (x), \nu_B (x) >, x \in X\}$$

Some fundamental operations of intuitionistic fuzzy sets are given below.

1. ***Complement:***

$$A' = \{< x, \nu_A (x), \mu_A (x) >, x \in X\}$$

2. ***Addition:***

$$A \oplus B = \{< x, \mu_A (x) + \mu_B (x) - \mu_A (x) \mu_B (x), \nu_A (x) \nu_B (x) >, x \in X\}$$

3. ***Multiplication:***

$$A \otimes B = \{< x, \mu_A (x) \mu_B (x), \nu_A (x) + \nu_B (x) - \nu_A (x) \nu_B (x) >, x \in X\}$$

2.3 Definition

Clothing cleanser or washing powder is a sort of cleanser (cleaning specialist) used for cleaning clothing. Normally, it is blended with concoction mixes including alkyl benzenesulfonates which are like cleanser; however, they are less influenced by hard water. While cleanser is as yet sold in powdered shape, fluid cleansers have been taking real pieces of the industry overall in numerous nations since their introduction in 1950s. As a rule, clothing cleansers contain water conditioners, surfactants, fade, chemicals, brighteners, and scents. Their detailing is emphatically influenced by the temperature of the cleaning water and differs nation to nation [19].

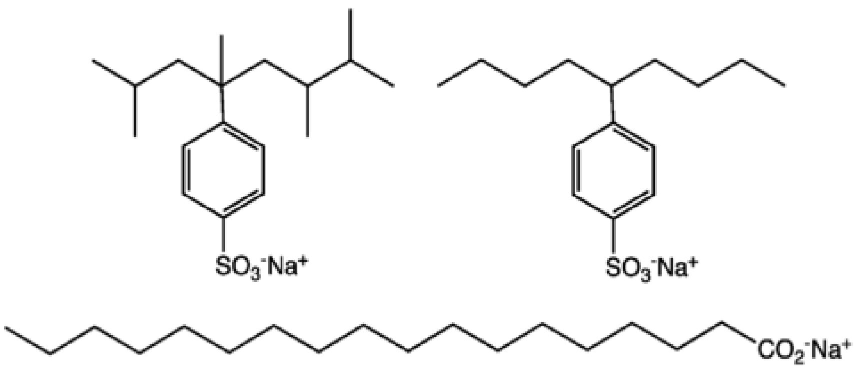


Figure 1. Structure of dsetergent

3. Problem Definition

When a person uses a washer, s/he generally selects the length of wash time based on some inputs. Optical sensors are used in the washer to detect inputs. The wash time is then determined from the information given. Until now, there has been no proper mathematical way to calculate the precise relationship between inputs and output. Consequently, this problem has remained unsolved until very recently. Fuzzy logic has been used as a result of a fuzzy logic-controlled washer controller which provides the approximately right wash time, even though an explicit model of the input / output relationship isn't out there.

3.1 Principles of Washing Machine

To understand how a washing machine cleans, we must understand its components.

3.2 Important Parts of Washing Machine

Water inlet control valve, water pump, tube (washer drum), agitator, motor, door safety sensor, detergent drawer, drain pipe, controller, and mechanical programmer.

3.3 Working Principle

The working rule of programmed clothes washer depends on fuzzy logic controller.

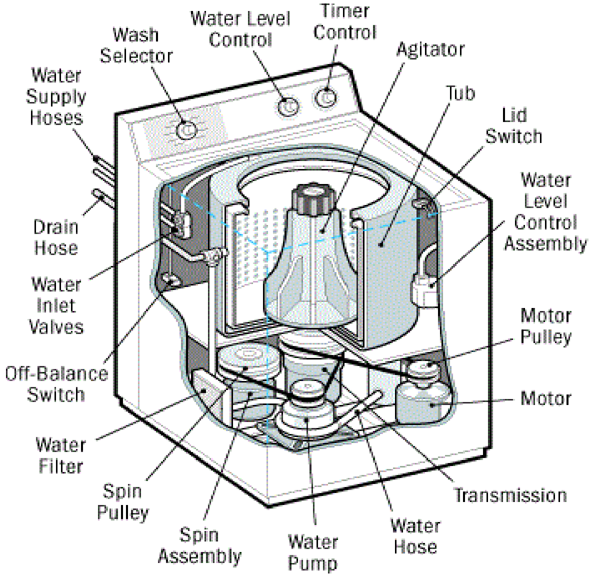


Figure 2. Working principle of washing machine

4. Basic Structure of the Proposed Model

The model for intuitionistic fuzzy values required for getting the amount of detergent for the above mentioned model is shown in Figure 3. The intuitionistic fuzzy inference system takes three input values (cloth type, dirt type, water pH) as shown in Table 1. These input values pass through the intuitionistic fuzzy controller process and then determine the amount of detergent. The basic structure of FLC for washer is shown in Figure 3.

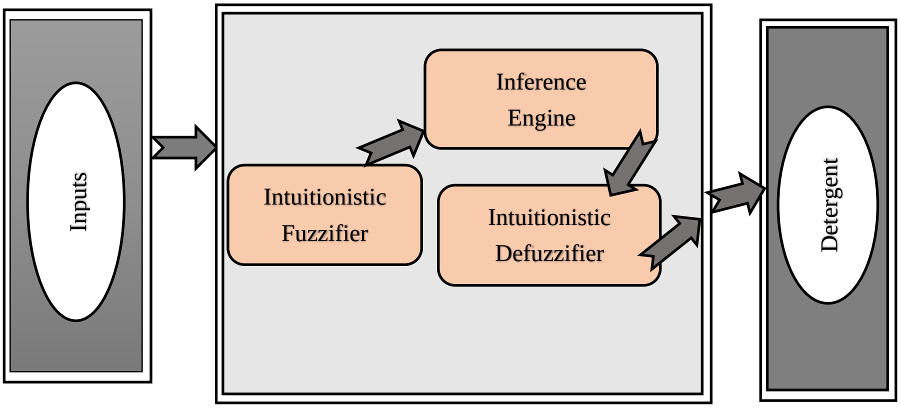


Figure 2. Proposed FLC model for IFNs

Table 1. Linguistic Input Values for Proposed FLC Model for IFNs

Linguistic Inputs	Linguistic Output
1) Cloth type	1) Detergent
2) Dirt type	
3) pH of water	

Membership and non-membership functions for the detergent can be expressed mathematically. Intuitionistic values of linguistic inputs (cloth type, dirt type, water pH) are used to calculate linguistic output results (detergent). Membership and non-membership functions are given in Table 2.

Table 2. Membership and Non-Membership Function Values for Linguistic Inputs

For Membership	For Non-Membership
$\mu_{cloth\_type} = \{0.2, 0.02, 0.2\}$	$\nu_{cloth\_type} = \{0.8, 0.98, 0.8\}$

$\mu_{jeans} = 0.2$	$v_{jeans} = 0.8$
$\mu_{cotton} = 0.02$	$v_{cotton} = 0.98$
$\mu_{parachute} = 0.2$	$v_{parachute} = 0.8$
$\mu_{dirt\_type} = \{0.22, 0.4\}$	$v_{dirt\_type} = \{0.78, 0.6\}$
$\mu_{oily} = 0.22$	$v_{oily} = 0.78$
$\mu_{non\_oily} = 0.4$	$v_{non\_oily} = 0.6$
$\mu_{water\_pH} = \{0.22, 0.04, 0.34\}$	$v_{water\_pH} = \{0.78, 0.96, 0.66\}$
$\mu_6 = 0.22$	$v_6 = 0.78$
$\mu_7 = 0.04$	$v_7 = 0.96$
$\mu_8 = 0.34$	$v_8 = 0.66$

5. Calculation

5.1 Linguistic FLC for Fuzzy Numbers

Saeed. M. *et. al.* [1] proposed a linguistic FLC system for an automatic washing machine. This controller takes three linguistic inputs: type of cloth, type of dirt and pH of water. Detergent is also considered as an output of the controller. The Membership Function (MF) of cloth type is (1-3), of dirt type is (1-2) and of pH of water is (1-3). Also, MF for detergent is between (1-10). The results and rules can be inferred from Table 2 of Saeed. M. *et. al.* [1].

5.2 Proposed Model for IFNs

Three linguistic inputs and one output were taken by considering the following mapping,

$$A: [0, 1] \rightarrow [0, 10]$$

5.2.1. Rules. 18 rules were defined by Saeed. M. *et. al.* [1] in their research. Keeping in view the same rules, FLC based on intuitionistic numbers was developed. Finally, defuzzification was done using the formula defined below. The rules were calculated by using the definition of an intuitionistic fuzzy set under addition, that is,

$$A \oplus B = \{< x, \mu_A(x) + \mu_B(x) - \mu_A(x)\,\mu_B(x), v_A(x)\,v_B(x) >, x \in X\}$$

Let A, B and C be the membership and non-membership values of cloth type, dirt type and water pH, respectively.

The calculation of rules is given below.

1. $A \oplus B = \{< x, 0.2 + 0.4 - (0.2)(0.4), (0.8)(0.6) >, x \in X\}$

$= \{< x, 0.52, 0.48 >, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{< x, 0.52 + 0.22 - (0.52)(0.22), (0.48)(0.78) >, x \in X\}$

$= \{< x, 0.6256, 0.3744 >, x \in X\}$

2. $A \oplus B = \{< x, 0.2 + 0.4 - (0.2)(0.4), (0.8)(0.6) >, x \in X\}$

$= \{< x, 0.52, 0.48 >, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{< x, 0.52 + 0.04 - (0.52)(0.04), (0.48)(0.96) >, x \in X\}$

$= \{< x, 0.5392, 0.4608 >, x \in X\}$

3. $A \oplus B = \{< x, 0.2 + 0.4 - (0.2)(0.4), (0.8)(0.6) >, x \in X\}$

$= \{< x, 0.52, 0.48 >, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{< x, 0.52 + 0.34 - (0.52)(0.34), (0.48)(0.34) >, x \in X\}$

$= \{< x, 0.6832, 0.1632 >, x \in X\}$

4. $A \oplus B = \{< x, 0.02+0.4-(0.02)(0.4), (0.98)(0.6)>, x \in X\}$

$= \{<x, 0.412, 0.588>, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{<x, 0.412, 0.22-(0.412)(0.22), (0.588)(0.78)>, x \in X\}$

$= \{<x, 0.54136, 0.45864>, x \in X\}$

5. $A \oplus B = \{< x, 0.02+0.4-(0.02)(0.4), (0.98)(0.6)>, x \in X\}$

$= \{<x, 0.412, 0.588>, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{<x, 0.412+0.04-(0.412)(0.04), (0.588)(0.96)>, x \in X\}$

$= \{<x, 0.43552, 0.27048>, x \in X\}$

6. $A \oplus B = \{< x, 0.02+0.4-(0.02)(0.4), (0.98)(0.6)>, x \in X\}$

$= \{<x, 0.412, 0.588>, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{<x, 0.412+0.34-(0.412)\,(0.34), (0.588)\,(0.66)>, x \in X\}$

$= \{<x, 0.61192, 0.38808>, x \in X\}$

7. $A \oplus B = \{< x, 0.2+ 0.4- (0.2)\,(0.4), (0.8)\,(0.6) >, x \in X\}$

$= \{<x, 0.52, 0.48>, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{<x, 0.52+ 0.22-(0.52)\,(0.22), (0.48)\,(0.78)>, x \in X\}$

$= \{<x, 0.6256, 0.3744>, x \in X\}$

8. $A \oplus B = \{< x, 0.2+ 0.4- (0.2)\,(0.4), (0.8)\,(0.6) >, x \in X\}$

$= \{<x, 0.52, 0.48>, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{<x, 0.52+0.04-(0.52)\,(0.04), (0.48)\,(0.96)>, x \in X\}$

$= \{<x, 0.5392, 0.4608>, x \in X\}$

9. $A \oplus B = \{< x, 0.2+ 0.4- (0.2)\,(0.4), (0.8)\,(0.6) >, x \in X\}$

$= \{<x, 0.52, 0.48>, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{<x, 0.52+0.34-(0.52)\,(0.34), (0.48)\,(0.34)>, x \in X\}$

$= \{<x, 0.6832, 0.1632>, x \in X\}$

10. $A \oplus B = \{< x, 0.2+ 0.22- (0.2)\,(0.22), (0.8)\,(0.78) >, x \in X\}$

$= \{<x, 0.376, 0.624>, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{<x, 0.376+0.22-(0.376)\,(0.22), (0.624)\,(0.78)>, x \in X\}$

$= \{<x, 0.51328, 0.48672>, x \in X\}$

11. $A \oplus B = \{< x, 0.2+ 0.22- (0.2)\,(0.22), (0.8)\,(0.78) >, x \in X\}$

$= \{<x, 0.376, 0.624>, x \in X\}$

Now,

$(A \oplus B) \oplus C = \{<x, 0.376+0.04-(0.376)\,(0.04), (0.624)\,(0.96)>, x \in X\}$

$= \{<x, 0.40096, 0.59904>, x \in X\}$

12. $A \oplus B = \{< x, 0.2+ 0.22- (0.2)\,(0.22), (0.8)\,(0.78) >, x \in X\}$

$= \{<x, 0.376, 0.624>, x \in X\}$

Now,
$(A \oplus B) \oplus C = \{<x, 0.376+0.34-(0.376)\,(0.34), (0.624)\,(0.66)>, x \epsilon X\}$
$= \{<x, 0.58816, 0.41184>, x \epsilon X\}$

13. $A \oplus B = \{< x, 0.02+ 0.22- (0.02)\,(0.22), (0.98)\,(0.78) >, x \epsilon X\}$
$= \{<x, 0.2356, 0.7644>, x \epsilon X\}$
Now,
$(A \oplus B) \oplus C = \{<x, 0.2356+0.22-(0.2356)\,(0.22), (0.7644)\,(0.78)>, x \epsilon X\}$
$= \{<x, 0.403768, 0.596232>, x \epsilon X\}$

14. $A \oplus B = \{< x, 0.02+ 0.22- (0.02)\,(0.22), (0.98)\,(0.78) >, x \epsilon X\}$
$= \{<x, 0.2356, 0.7644>, x \epsilon X\}$
Now,
$(A \oplus B) \oplus C = \{<x, 0.2356+0.04-(0.2356)\,(0.04), (0.7644)\,(0.96)>, x \epsilon X\}$
$= \{<x, 0.266176, 0.733824>, x \epsilon X\}$

15. $A \oplus B = \{< x, 0.02+ 0.22- (0.02)\,(0.22), (0.98)\,(0.78) >, x \epsilon X\}$
$= \{<x, 0.2356, 0.7644>, x \epsilon X\}$
Now,
$(A \oplus B) \oplus C = \{<x, 0.2356+0.34-(0.2356)\,(0.34), (0.7644)\,(0.66)>, x \epsilon X\}$
$= \{<x, 0.495496, 0.504504>, x \epsilon X\}$

16. $A \oplus B = \{< x, 0.2+ 0.22- (0.2)\,(0.22), (0.8)\,(0.78) >, x \epsilon X\}$
$= \{<x, 0.376, 0.624>, x \epsilon X\}$
Now,
$(A \oplus B) \oplus C = \{<x, 0.376+0.22-(0.376)\,(0.22), (0.624)\,(0.78)>, x \epsilon X\}$
$= \{<x, 0.51328, 0.48672>, x \epsilon X\}$

17. $A \oplus B = \{< x, 0.2+ 0.22- (0.2)\,(0.22), (0.8)\,(0.78) >, x \epsilon X\}$
$= \{<x, 0.376, 0.624>, x \epsilon X\}$
Now,
$(A \oplus B) \oplus C = \{<x, 0.376+0.04-(0.376)\,(0.04), (0.624)\,(0.96)>, x \epsilon X\}$

= {<x, 0.40096, 0.59904>, x ϵ X}

18. A ⊕ B = {< x, 0.2+ 0.22- (0.2) (0.22), (0.8) (0.78) >, x ϵ X}
= {<x, 0.376, 0.624>, x ϵ X}
Now,
(A ⊕ B) ⊕ C = {<x, 0.376+0.34-(0.376) (0.34), (0.624) (0.66)>, x ϵ X}
= {<x, 0.58816, 0.41184>, x ϵ X}

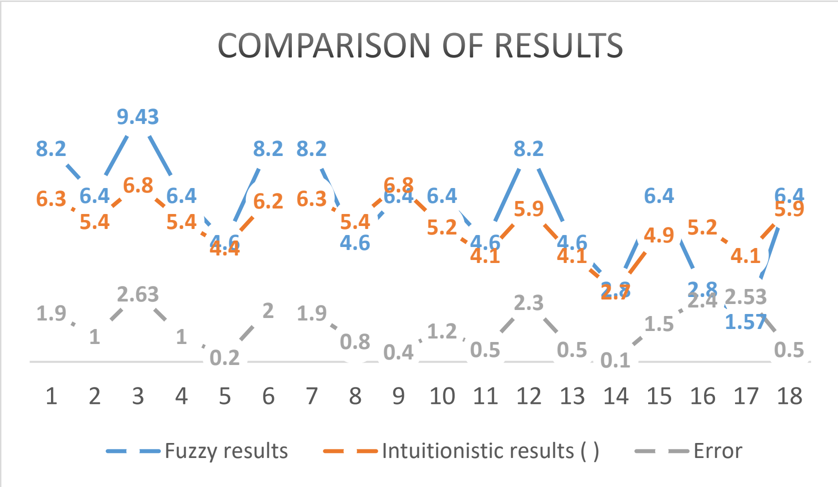
The comparison of fuzzy results (in Saeed. M *et al.* [1]) with intuitionistic results calculated above is shown in Table 3.

Table 3. Comparison of Results between FLCs based on Fuzzy and Intuitionistic Numbers

Rule No.	**Fuzzy Results**	**Intuitionistic Results (μ_{output})**	**Error**
1	8.2	6.3	1.9
2	6.4	5.4	1
3	9.43	6.8	2.63
4	6.4	5.4	1
5	4.6	4.4	0.2
6	8.2	6.2	2
7	8.2	6.3	1.9
8	4.6	5.4	0.8
9	6.4	6.8	0.4
10	6.4	5.2	1.2
11	4.6	4.1	0.5
12	8.2	5.9	2.3
13	4.6	4.1	0.5
14	2.8	2.7	0.1
15	6.4	4.9	1.5
16	2.8	5.2	2.4
17	1.57	4.1	2.53
18	6.4	5.9	0.5

6. Results, Discussion and Conclusion

The conclusion can be drawn from the linguistic results shown in Graph 1. When the consumer chooses water with pH 7, then the amount of detergent for laundry process is quite small as compared to when the consumer chooses water with pH 6 and 8. We have been able to justify these results by the use of the FLC method. We found the approximate results to that of fuzzy results via Intuitionistic FLC. We solved these fuzzy linguistic results numerically. Actually, intuitionistic FLC is a method that belongs to artificial intelligence and traditional theory.



Graph 1. Comparison between FLC based on Fuzzy and Intuitionistic Numbers

We designed the model of intuitionistic FLC in which we determined the values for three inputs (cloth type, dirt type, water pH) and obtained the amount of detergent as output with the help of intuitionistic fuzzy inference technique. In Table 3, we depicted both fuzzy results and intuitionistic results and the error was calculated between them. The working of this paper allows us to say that the selection of detergent in laundry process is much more reliable and updated. Especially, it makes the washing machine much more automatic as compared to those that use simple fuzzy logic or the traditional control system design methodology.

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