Batch: A1 Roll No.: 16010120015

Experiment No. 10

Grade: AA / AB / BB / BC / CC / CD /DD

Signature of the Staff In-charge with date

Title: Case study on Fuzzy Inference System

Aim : To apply fuzzy logic and determine the time required to run a Washing machine, given the amount of dirt and grease on clothes.

Expected Outcome of Experiment:

CO4 : Apply basics of Fuzzy logic and neural networks

Books/ Journals/ Websites referred:

https://www.researchgate.net/publication/326348482_Design_and_Simulation_of_Washing_Machine_using_Fuzzy_Logic_Controller_FLC/link/5b474aaaa6fdccadaec1e057/download

Pre Lab/ Prior Concepts:

Fuzzification:

It is the method of transforming a crisp quantity into a fuzzy quantity. This can be achieved by identifying the various known crisp and deterministic quantities as completely nondeterministic and quite uncertain in nature. This uncertainty may have emerged because of vagueness and imprecision which then lead the variables to be represented by a membership function as they can be fuzzy in nature

Fuzzification is a module or component for transforming the system inputs, i.e., it converts the crisp number into fuzzy steps. The crisp numbers are those inputs which are measured by the sensors and then fuzzification passed them into the control systems for further processing. This component divides the input signals into following five states in any Fuzzy Logic system:

- Large Positive (LP)
- Medium Positive (MP)
- Small (S)
- Medium Negative (MN)

- Large negative (LN)

Defuzzification:

It is the inversion of fuzzification, there the mapping is done to convert the crisp results into fuzzy results but here the mapping is done to convert the fuzzy results into crisp results. This process is capable of generating a nonfuzzy control action which illustrates the possibility distribution of an inferred fuzzy control action. Defuzzification process can also be treated as the rounding off process, where fuzzy set having a group of membership values on the unit interval reduced to a single scalar quantity.

Defuzzification is a module or component, which takes the fuzzy set inputs generated by the Inference Engine, and then transforms them into a crisp value. It is the last step in the process of a fuzzy logic system. The crisp value is a type of value which is acceptable by the user. Various techniques are present to do this, but the user has to select the best one for reducing the errors.

Fuzzy rule base

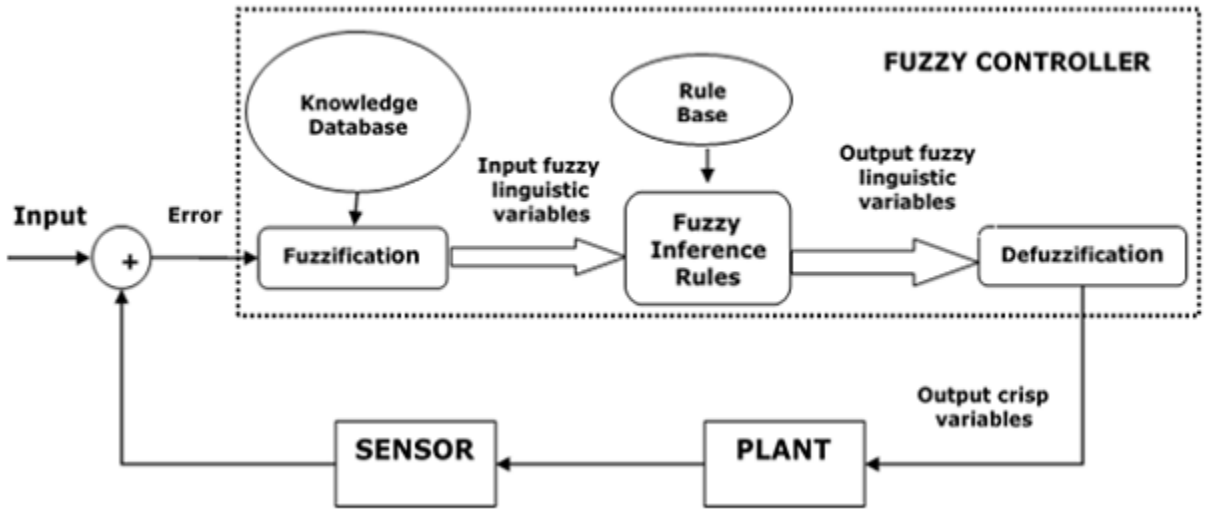
Rule Base is a component used for storing the set of rules and the If-Then conditions given by the experts are used for controlling the decision-making systems. There are so many updates that come in the Fuzzy theory recently, which offers effective methods for designing and tuning of fuzzy controllers. These updates or developments decreases the number of fuzzy set of rules.

Membership functions

The membership function is a function which represents the graph of fuzzy sets, and allows users to quantify the linguistic term. It is a graph which is used for mapping each element of x to the value between 0 and 1. This function is also known as indicator or characteristics function. This function of Membership was introduced in the first papers of fuzzy set by Zadeh. For the Fuzzy set B, the membership function for X is defined as: $\mu B:X \rightarrow [0,1]$. In this function X, each element of set B is mapped to the value between 0 and 1. This is called a degree of membership or membership value.

Designing of Fuzzy Controller

The following diagram shows the architecture of Fuzzy Logic Control (FLC).



Major Components of FLC

Followings are the major components of the FLC as shown in the above figure −

- **Fuzzifier** − the role of fuzzifier is to convert the crisp input values into fuzzy values.
- **Fuzzy Knowledge Base** − It stores the knowledge about all the input-output fuzzy relationships. It also has the membership function which defines the input variables to the fuzzy rule base and the output variables to the plant under control.
- **Fuzzy Rule Base** − It stores the knowledge about the operation of the process of domain.
- **Inference Engine** − It acts as a kernel of any FLC. Basically it simulates human decisions by performing approximate reasoning.
- **Defuzzifier** − The role of defuzzifier is to convert the fuzzy values into crisp values getting from fuzzy inference engine

Steps in Designing FLC

Following are the steps involved in designing FLC −

- **Identification of variables** − Here, the input, output and state variables must be identified of the plant which is under consideration.
- **Fuzzy subset configuration** − the universe of information is divided into number of fuzzy subsets and each subset is assigned a linguistic label. Always make sure that these fuzzy subsets include all the elements of universe.
- **Obtaining membership function** − Now obtain the membership function for each fuzzy subset that we get in the above step.

- **Fuzzy rule base configuration** − Now formulate the fuzzy rule base by assigning relationship between fuzzy input and output.
- **Fuzzification** − the fuzzification process is initiated in this step.
- **Combining fuzzy outputs** − by applying fuzzy approximate reasoning, locate the fuzzy output and merge them.
- **Defuzzification** − finally, initiate defuzzification process to form a crisp output.

Overall steps in designing a fuzzy logic controller:

Step 1: Locate the input, output and state variables of the plant under consideration.

Step 2: Split the complete universe of discourse spanned by each variable into a number of fuzzy subsets, assigning each with a linguistic label. The subsets include all the elements in the universe.

Step 3: Obtain the membership function for each fuzzy subset.

Step 4: Assign the fuzzy relationships between the inputs or states of fuzzy subsets on one side and the outputs of fuzzy subsets on other side, thereby forming the rule base.

Step 5: Choose appropriate scaling factors for the input and output variables for normalizing the variables between [0, 1] and [−1, 1] interval.

Step 6: Carry out the fuzzification process.

Step 7: Identify the output contributed from each rule using fuzzy approximate reasoning.

Step 8: Combine the fuzzy outputs obtained from each rule.

Step 9: Finally, apply defuzzification to form a crisp output.

Research Paper :

Design and Simulation of Washing Machine using Fuzzy Logic Controller (FLC)

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Research Paper Link : https://iopscience.iop.org/article/10.1088/1757-899X/384/1/012044/pdf

Abstract.

This Research paper aims to design and simulate Fuzzy Logic control system in washing machine. Washing machine is one of the main machines in the household. Therefore it is necessary to control the washing machine system to facilitate the user, reduce the time, electricity consumption, and water in washing water. Fuzzy Logic is an efficient approach in complex control systems compared to conventional approaches. In this paper, Fuzzy Logic control is used to determine the value of washing speed based on 4 different inputs and the stability of motor speed of washing machine based on 3 inputs. The stability setting of the motor speed of the washing machine is controlled to have a constant speed despite the load changes. In the washing speed control system, the output is the value of washing speed. Based on the value of the output, the input value is a reference speed that will be processed on the motor stability control system. The output generated on this system is a control voltage for the inverter, which in case of input changes in the other two inputs will not affect the output value. In paper in, the washing machine control system is designed and simulated using Fuzzy logic toolbox in Matlab.

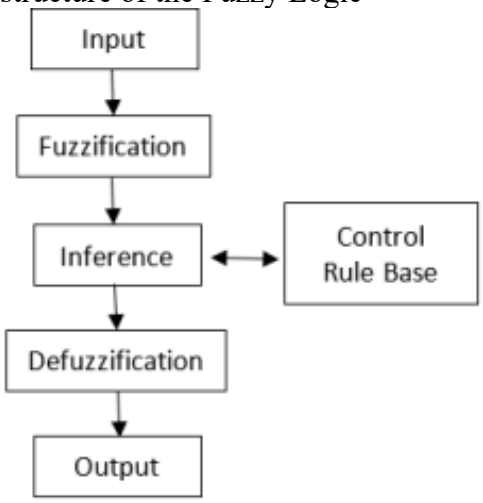
Introduction

One of the main machines in the household is the washing machine.The technology of using sensors in washing machines started to be applied.
Timer is used to determine the time the machine will work. With the ever-evolving technology, the use of microcontroller is being applied in the washing process based on predetermined time In addition, the technology of using sensors in washing machines started to be applied .

The washing machine control system has started using Fuzzy Logic as its controller . The use of Fuzzy Logic controls is easier to implement than conventional controls such as PID
The speed of an induction motor is affected by changing the load given. In addition, the speed control performance of the washing machine is also influenced by the effects of mechanical and electrical subsystems

A washing machine control system using Fuzzy Logic. The controlled parameters are washing speed based on the weight input of clothing, the type of defilement, the level of dirtiness, and the sensitivity of clothing Fuzzy Logic controls are smart system controls. They have the ability to solve problems on complex systems that are not owned by conventional controllers .
The value becomes input as reference value of motor speed. In this system there will be 2 other input that is error and derror. The output value of motor stability control system will not affect the value of error and derror given

The basic structure of the Fuzzy Logic



In the fuzzification process, there is a conversion of crisp input values into fuzzy values through mapping techniques of input variables into membership functions and truth values

Membership function sets the function to declare membership of a value. There are several forms of membership functions such as triangular, trapezoidal. Each rule on fuzzy will relate to another fuzzy relation. Generally fuzzy rules are expressed in the form of IF-THEN logic.

Evaluate fuzzy rules to generate the output of each rule. The input of the defuzzification process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a number in the fuzzy set domain. So if given a set fuzzy within a certain range, then it should be taken a certain crisp value as output.

Implementation of the Fuzzy Logic Control System

The system flow diagram of the process is shown

The person generally select the length of wash time to wash based on the amount of clothes wish to wash and type and degree of dirt clothes have. To automate this process we use sensors to detect these parameters (i.e. type of clothes, type of dirt and dirtiness of clothes). The wash time is then determined from this data. Unfortunately, there is no easy way to formulate a precise mathematical relationship between lengths of wash time required.

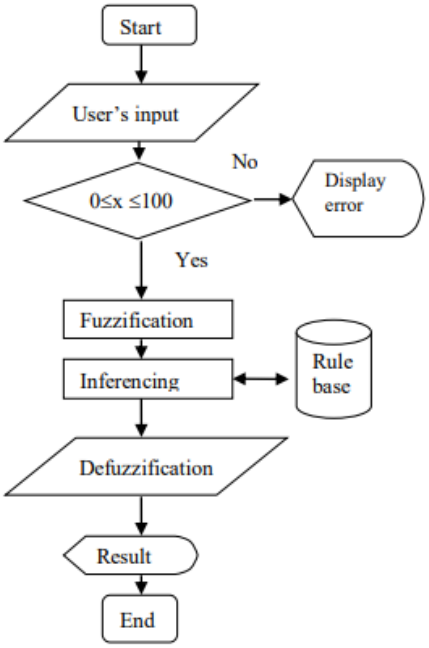


Fig.1 .System flow of the process

Diagram :

The control system simulation and make the design of Fuzzy Logic system using Fuzzy Logic Controller Simulink

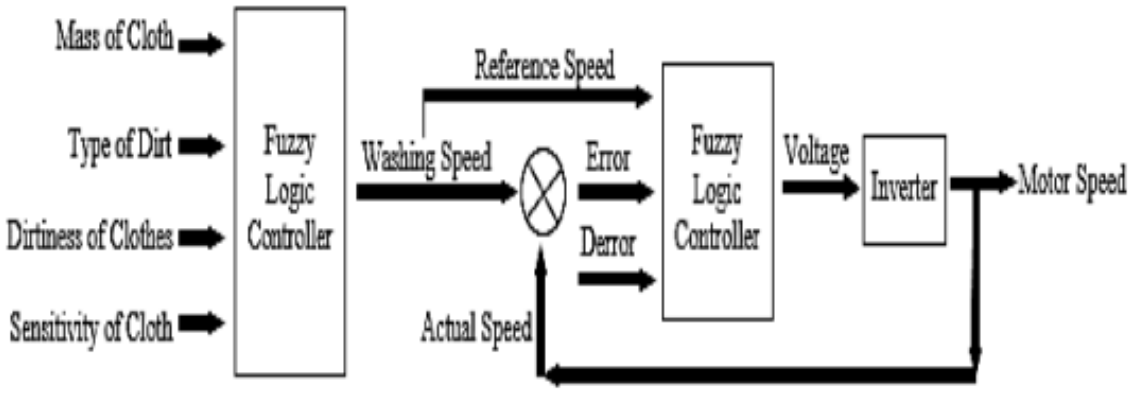


Figure 2. Proposed System.

- The first fuzzy logic control system is used in determining the washing speed with 4 inputs. These 4 inputs can be provided manually or automatically by using the corresponding sensor
- These 4 inputs can be provided manually or automatically by using the corresponding sensor

- After the first system produces the output the system then performs a process whereby the output on the first system is defined as the reference speed at the second system input
- The second system runs the process of regulating motor speed stability with 3 inputs.

In fuzzy logic, crisp inputs are converted into fuzzy inputs. So, membership functions are created to represent each crisp input depending on linguistic terms and their ranges

Input Parameters:

1) Type of clothes (TC)
2) Amount of clothes (AC)
3) Amount of dirtiness (AD)

Output Parameters:

1) Wash time (Wash)
2) Rinse time (Rinse)
3) Spin time (Spin)

Fuzzy Inputs

Figure2. Membership Function of Type of Clothes

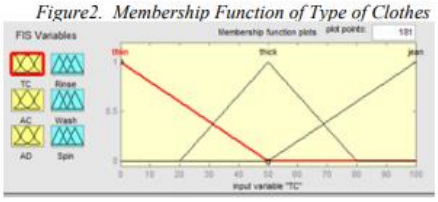


Figure3. Membership Function of Amount of Clothes

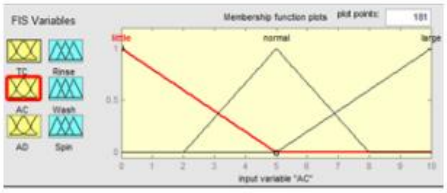
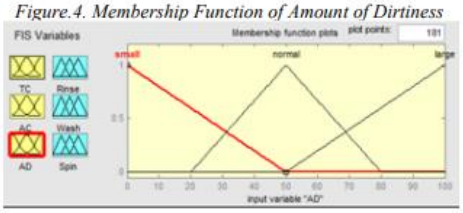


Figure.4. Membership Function of Amount of Dirtiness



Fuzzy Outputs

Figure. 5. Membership Function of Rinse Time

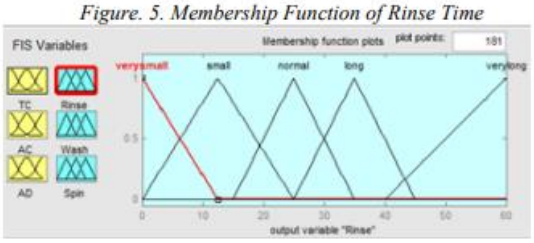


Figure. 6. Membership Function of Wash Time

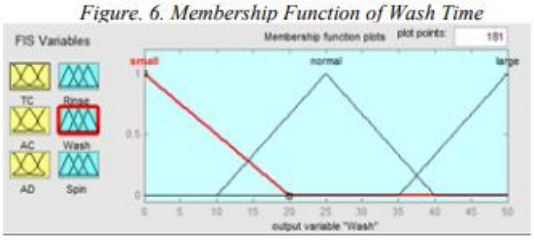


Figure. 7. Membership Function of Spin Time

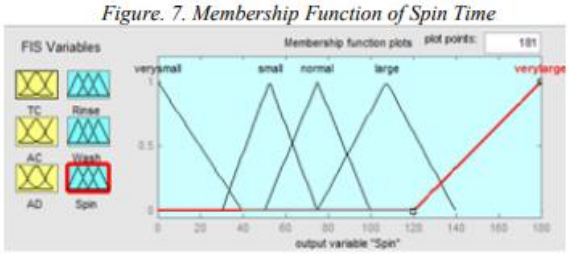


Figure 8. Output membership function used are triangle and trapezium.

Table 2. If-Then Rules.

No	RS	E	DE	VC
1	VS	NB	NB	VL
2	VS	NB	NS	VL
3	VS	NB	Z	VL
4	VS	NB	PS	VL
5	VS	NB	PB	VL
6	VS	NS	NB	VL
7	VS	NS	NS	VL
8	VS	NS	Z	VL
9	VS	NS	PS	VL
10	VS	NS	PB	VL
…	…	….	…	…
125	VF	PB	PB	VH

Notes: VS=Very Slow, S=Slow, M=Medium, F=Fast, VF=Very Fast, NB=Negative Big, NS=Negative Small, Z=Zero, PS=Positive Small, PB=Positive Big, VL=Very Low, L=Low, H=High, VH=Very High.

The inference system used is the Mamdani Method. In this method the implication function used is Min that is in implies a rule takes its minimum value. As for the method of defuzzification used the method of Center of Gravity (CoG) or another name centroid. In this method the crisp output value is obtained by enchanting the center point (z *) fuzzy area. The output on this system will be forwarded to the next system.

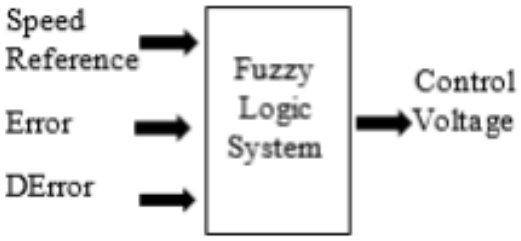


Figure 6. Fuzzy Logic Control for induction motor speed.

In this model the input parameters are reference speed, error, and derror value. The reference speed is obtained from the previous system output. Error is the difference between set point speed and actual speed. Derror is the current error increment with the previous error. While output is a voltage (volts) that will be given to the inverter as a control voltage to run the motor. Membership functions used are triangle and trapezium.

Results and Discussion

Using Fuzzy Logic controls can result in different washing rates according to different inputs on the weight of clothing, the type of impurity, the level of impurities, and the sensitivity of clothing.

For example, the case on the first system will be given 40 inputs on the weight of the clothing, 20 on the type of clothing defilements, 20 on the level of clothing defilements, and 30 on the clothing sensitivity. The data is influenced by 8 rules, after doing the implications on the rule is taken minimum value. Once we get the implication function of each rule in use Max method to do the composition between all rules. So, get the output area can be seen

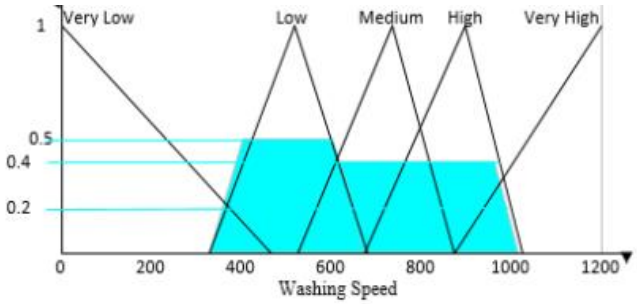


Figure 9. Graph of the Composition of the Rules (The data is influenced by 8 rules).

It can be seen in Figure 11 shows a surface response relationship between input and output on the case of washing speed. Figure 12 shows the response surface of the relationship between the input and output on the stability control system of induction motor speed.

Despite the change in input error and derror values. For example, given the reference value of the speed of the first system output value of 600 rpm, error = 100 and derror = 100. The data is influenced by 4 rules, after doing the implications of the rule is taken the minimum value. Once we get the implication function of each rule in use Max method to do the composition between all rules

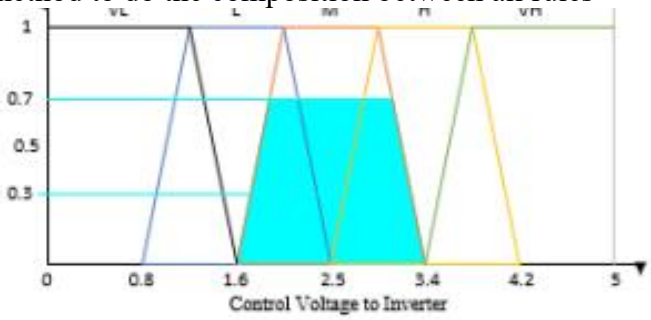


Figure 10. Graph of the Composition of the Rules (The data is influenced by 4 rules).

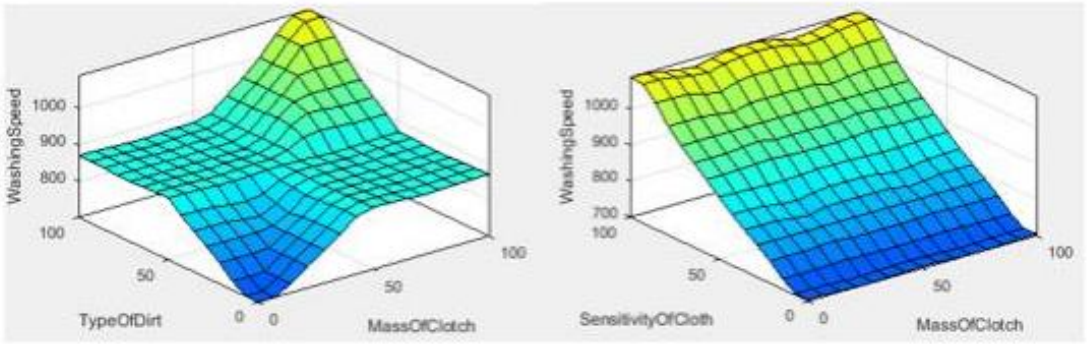


Figure 11. Surface response relationship between input and output on the case of washing speed.

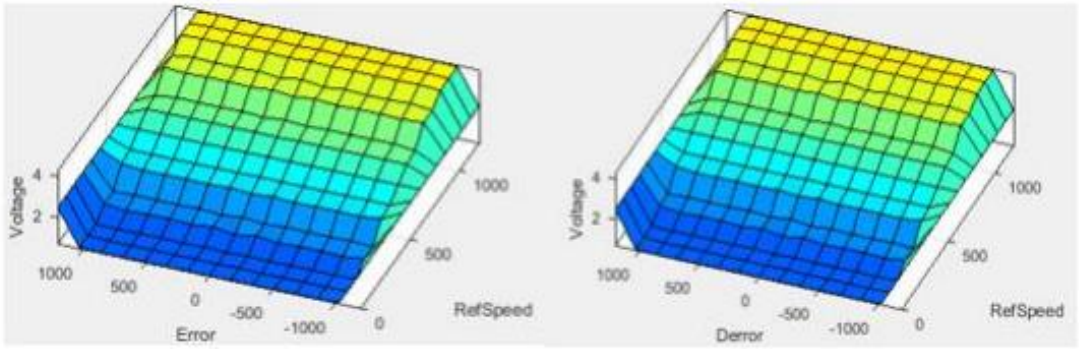


Figure 12. Surface response relationship between input and output on the stability control system of induction motor speed.

Conclusion:

In this paper, developing fuzzy logic for washing machines

- Fuzzy Logic help improve automation systems in washing machines and reduce electricity, water and time consumption. Based on the weight of clothing detected by the weight sensor, while other input parameters.
- The parameters can determine the appropriate washing speed.
- The results of the washing speed can enter the next control system to stabilize the motor speed despite any changes in load.
- Using a fuzzy logic system is easier to implement into complex systems than conventional controls.

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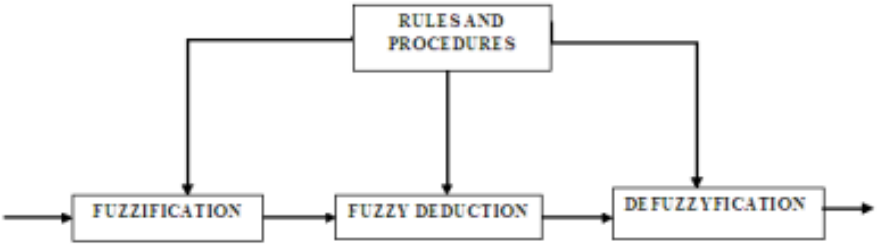
Post lab question:

1. Explain application of fuzzy logic in image processing.

The applications of fuzzy logic once thought to be an ambiguous scientific interest can be found in many engineering and technical works. Fuzzy logic has been used in various applications such as facial pattern recognition, air conditioners, washing machines, vacuum cleaners, braking systems, and transmission systems, control of subway systems and unmanned helicopters, knowledge-based systems for multi objective optimization of power systems, weather forecasting systems, models for new product pricing or project risk assessment, medical diagnosis and treatment plans, and stock trading.

Fuzzy logic has been effectively used in several fields such as control systems engineering, image processing, power engineering, industrial automation, robotics, consumer electronics, and optimization. This branch of mathematics has inspired new life into systematic fields that have been latent for a long time.



Fuzzy logic is a logical system which is an extension of multi-valued logic.

In logics system multi-valued logic is a propositional calculus in which there are more than two truth values. There are only two possible values true or false for any proposition but extension to classical two valued logic is an n-valued logic or n greater than two. Fuzzy logic is conceptually easy to understand and is flexible and is tolerant of imprecise data.

Date: ___30/11/2022__ **Signature of faculty in-charge**