An Automated Fuzzy Logic Controlled Water Heater

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Abstract

Fuzzy logic is a rule-based decision process that seeks to solve problems where the system is difficult to model and where ambiguity or vagueness is abundant between two extremes. Fuzzy logic allows the system to be defined by logic equations rather than complex differential equations. Fuzzy logic incorporates ways of thinking, which allows modeling complex systems using human's knowledge and experience. This thesis implements for justifying the power of water heater according to the temperature and the quantity of water being used. The fuzzy controller fuzzifies these inputs with respect to the input membership functions. Then the controller operates according to the specified rules which is built by FAM table and give the fuzzy output values .After that this fuzzy output values is defuzzified to achieve the crisp values of real world heating power values for the water heater. Water heater is one of the applications in use today.

1. Introduction

. Fuzzy logic has been used in a wide range of problem domains. Fuzzy logic is relatively used in wide areas of applications: process control, management and decision making, operations research, economics and classification. Fuzzy set is a set whose elements have degrees of membership function. The element of a fuzzy set can be full member (100%membership) or a partial member (between 0% and 100%membership).That is, the membership values assigned to and element is no longer restricted to just two values, but can be 0, 1 or any value in-between. Mathematical function which defines the degree of an element's membership in a fuzzy set is called membership function. The natural description of problems, in linguistic terms, rather than in terms of relationships between precise numerical values is the major advantage of theory. Fuzzy Control, a relatively new, intelligent, knowledge based control technique performs exceptionally well in nonlinear, complex.

Thus the use of fuzzy logic for water heater system (WHS) seems to be promising. These are certain difficulties in modeling and simulating complex real world control system development Fuzzy control provides a formal methodology for representing, manipulating and implementing a heuristic knowledge about how to control the system. In order to apply the fuzzy logic in a real world application, a fuzzy logic control system for the determination of the heating power of a water heater is proposed in this thesis.

2. General Fuzzy Control System

The fuzzy controller as an artificial decision maker operates in a closed-loop system in real time. Fuzzy controller as shown in figure is composed of the following four elements:

1 .identify the inputs and outputs using linguistic variable;
2. assign membership function to the variable;
3. build a rule base;
4. generate a crisp control action (defuzzification)

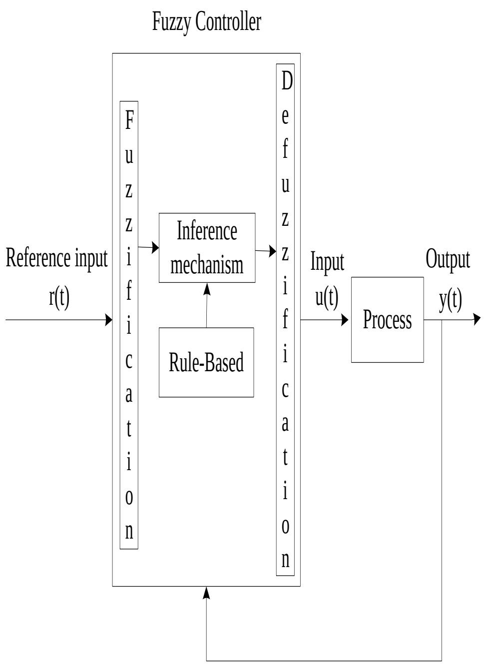

Figure 1. Basic Block Diagram of Fuzzy Controller

The linguistic variables, membership function, and the rule base stem form the experience of a skilled operator. The operation of a fuzzy controller consists of four stages. First, a measurement must be taken of the state variables to be monitored during the process. Next, these values must be translated by a component known as a condition interface into fuzzy linguistics terms; these terms are specified by the membership functions of the fuzzy sets, which are defined on the appropriate universe of discourse.

These linguistics terms are then used in the evaluation of the fuzzy control rules. The results of application of the rules are itself a fuzzy set defined on the universe of possible control actions. Finally, based on this fuzzy set, the component called an action interface must produce the crisp control action (defuzzification), which is been executed.

3. Fuzzy Logic Controlled Water Heater

Fuzzy logic is used for controlling a wide variety of devices. Fuzzy logic has been used in application that are variable to convention control algorithm on the basic of mathematical modern of the system being controlled. Fuzzy logic has a particular advantage in areas where precise description of the control process is impossible and is this especially suited to support the heating elements power.

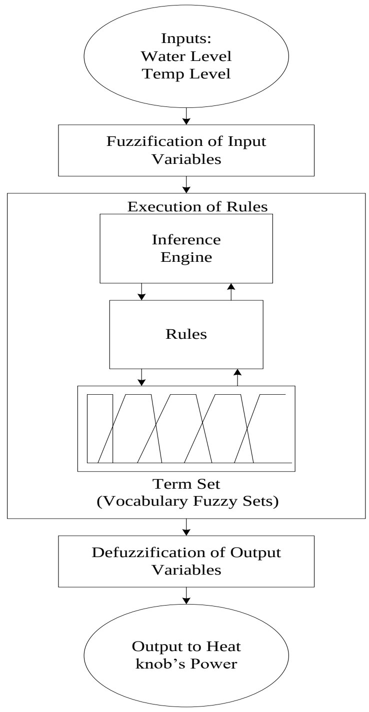

Figure 2. System Flow Diagram for Fuzzy Logic Controlled Water Heater

This system will accept Temperature (T) and Water Level (W) as the input values to make fuzzification. After that related fuzzy set values and membership values can be achieved and viewed in the graphically forms as well as text format as required. By minimizing previous membership value, $\mu_{premise}$ values, as a result, are achieved. In the view of inference mechanism, fuzzy conclusion can be made by matching with Rule-base built by data and $\mu_{premise}$ value by making fuzzification.

Consequently, these fuzzy conclusions can be defuzzification to set output value by means defuzzification methods, COG (center of gravity).

4. System Implementation

4.1. Fuzzification for Inputs and Output

There will be "linguistic variables" that describe each of the time-varying fuzzy controller inputs and outputs. Fuzzy controller inputs variables are as follows:

"Temperature" describes T (°C)

"Water level" describes W (Liters)

Fuzzy controller output variables are as follows:

"Power" describes P (W)

Temperature, Water Level and Power of heat knob are taken as the following linguistic variables.

Linguistic variables for Water Level can be also expressed as "linguistic-numeric " in seven levels.

Shorter description integers can be used as follow:

"0" is used to represent "zero" or "Z"
"1" is used to represent "very small" or "VS"
"2" is used to represent "too small" or "TS"
"3" is used to represent "smaller than optimum" or "SO"
"4" is used to represent "optimum" or "OP"
"5" is used to represent "too large" or "TL"
"6" is used to represent "very large" or "VL"

Table 1. Fuzzy membership function for water level

Crisp Input Range	Fuzzy variable
0-25/6	Zero
0-50/6	Very Small
25/6-50/6	Too Small
50/6-75/6	Smaller Than Optimum
75/6-100/6	Optimum
100/6-125/6	Too Large
25	Very Large

To construct the membership functions:

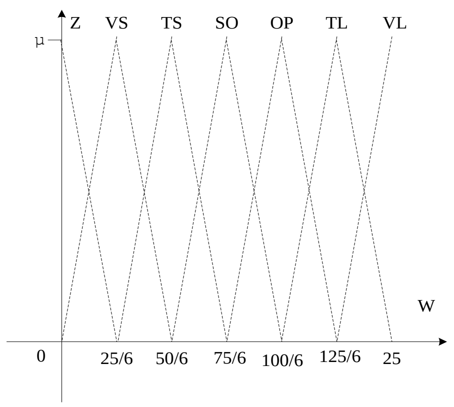

Figure 1. Input membership functions for Water Level with input values

Linguistic variables for Temperature can be also expressed as "linguistic-numeric value" in seven levels.

Shorter description integers can be used as follow.

"0" is used to represent "zero" or "Z"
"1" is used to represent "very small" or "VS"
"2" is used to represent "too small" or "TS"
"3" is used to represent "smaller than optimum" or "SO"
"4" is used to represent "optimum" or "OP"
"5" is used to represent "too large" or "TL"
"6" is used to represent "very large" or "VL"

Assign membership function to the variable

Table 2. Fuzzy variable ranges for Temperature

Crisp Input Range	Fuzzy variable
0-12.5	Zero
0-25	Very Small
12.5-37.5	Too Small
25-50	Smaller Than Optimum
37.5-62.5	Optimum
50-75	Too Large
62.5-75	Very Large

To construct the membership functions:

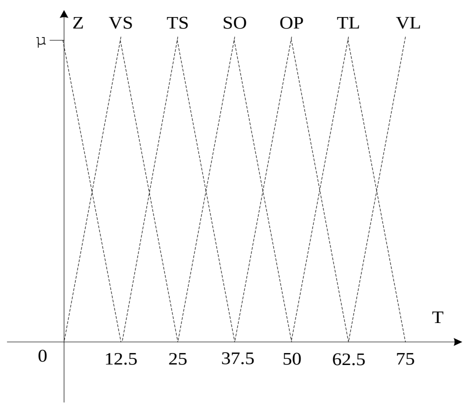

Figure 2. Input membership functions for Temperature with input values

Linguistic variables for "Power" can be also expressed as "linguistic-numeric value" in six levels.

Shorter description integers can be used as follow.

"0" is used to represent "zero" or "Z"
"1" is used to represent "very small" or "VS"

"2" is used to represent "too small" or "TS"
"3" is used to represent "smaller than optimum" or "SO"
"4" is used to represent "optimum" or "OP"
"5" is used to represent "too large" or "TL"
"6" is used to represent "very large" or "VL"

Assign membership function to the variable

Table 3. Fuzzy variable ranges for Power

Crisp Input Range	Fuzzy variable
0-1	Zero
0-2	Very Small
1-3	Too Small
2-4	Smaller Than Optimum
3-5	Optimum
4-6	Too Large
5-6	Very Large

To construct the membership functions:

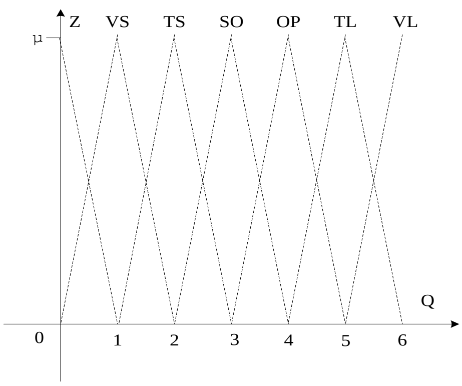

Figure 3: Output membership functions for power with output values

4.2. Fuzzy (Rule-Based) Systems

The convenient way to list all possible rules for the case where there are not too many inputs to the fuzzy controller is to use FAM table. Fuzzy rules can be defined according to the values of inputs from heat knob. Fuzzy associated memories (FAM) table has to be constructed to get the best solution according to the fuzzy inputs.

Table 4. Fuzzy Associative Memory (FAM) Table of the System

Power			Water Level						
			0	1	2	3	4	5	6
			Z	VS	TS	SO	OP	TL	VL
Temperature	0	Z	0	0	1	1	1	2	2
	1	VS	1	2	2	2	2	2	3
	2	TS	1	2	2	2	3	3	4
	3	SO	1	2	2	3	3	4	4
	4	OP	1	2	3	3	4	4	5
	5	TL	1	2	3	4	5	5	5
	6	VL	2	3	4	5	5	5	5

4.3 Defuzzification for Heat Knob's Output Power

According to the rule base (FAM table) together with the inference mechanism, output membership function together with the output fuzzy value, is obtained. After this output fuzzy value is defuzzified, the crisp value of Water Heater's output power is achieved. Defuzzification is the conversion of a fuzzy quantity to a precise (crisp) quantity. There are seven defuzzification methods. Among them, Center of Gravity method is used in this design because this method is the most prevalent and physically appealing of all the defuzzzification methods. Center of Gravity (COG) method computesμ^{crisp} to be

$$\mu^{crisp} = \frac{\sum_i b_i \int \mu_{premise(i)}}{\sum_i \int \mu_{premise(i)}}$$

where,

$\sum$ =denotes the algebraic sum

b_i =area of membership function

$\int \mu_{premise}$ =center of membership function

5. Computer Simulation of the System

The following three figures show the computer simulation of the operation of this system. Figure 6 shows that user can give the input values as water level of 20 Liters and temperature of 40 °C. The membership functions graph of specified input ranges and output ranges are also shown in figure 7. This system fuzzified with respect to the two inputs to get the corresponding fuzzy values with respect to the membership functions concerned. According to the rule base (FAMs table) together with the inference mechanism, output membership function together with the output fuzzy value, is obtained. The output fuzzified value is shown in figure 6 and its graph representation is shown in Figure 8. This fuzzy output is defuzzified to get the crisp value of power which is shown in Figure 8.

Figure 6. Calculated Results using Fuzzy Logic after giving Input values

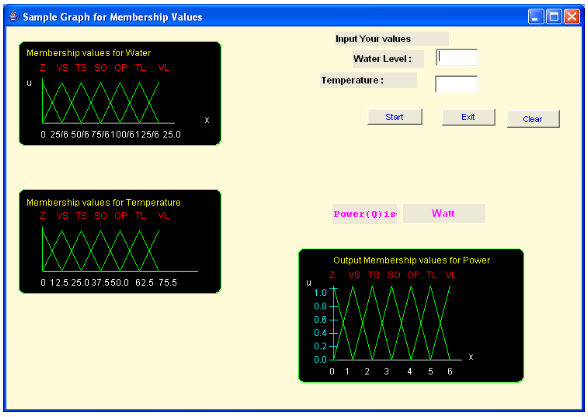

Figure 7. Calculated Membership Function for Inputs and Output Data

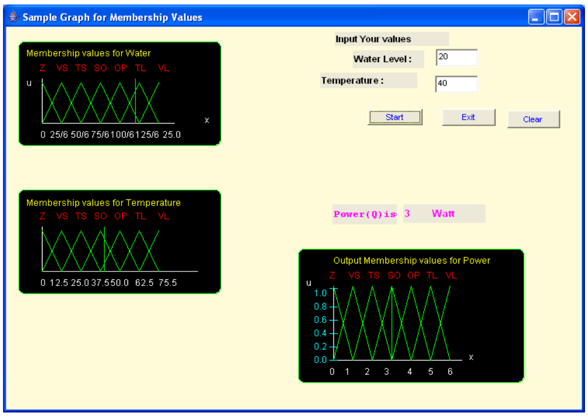

Figure 8. Fuzzified Output and defuzzification Result

6. Experimental Results

The fuzzy associated memories (FAM) table has to be constructed to get the best solution according to the acquired fuzzy inputs. The water level (WL) and temperature (T) at the input of the fuzzy controllers are also converted into fuzzy values. The membership functions of using the rule-base method, the output regions are mapped into the FAM table.

Table 5. Water Level (W) and its fuzzy values

No	WL	Fuzzy Value	
		F1	F2
1	2	0.52	0.48
2	4.17	0.999	7.999
3	8	0.080	0.919
4	10	0.600	0.399
5	15	0.400	0.599
6	20	0.199	0.800
7	25	-0.0	1.0

Table 6. Temperature (T) and its fuzzy values

No	WL	Fuzzy Value	
		F1	F2
1	5	0.6	0.4
2	15	0.8	0.2
3	25	-0.0	1.0
4	35	0.2	0.8
5	45	0.4	0.6
6	55	0.6	0.4
7	65	0.8	0.2

Table 7. The magnitude of output power by water level and temperature its rate

WL	2	4.17	8	10	15	20	25
5	0.855	0.403	0.741	1.235	1.444	1.643	2.0
15	1.1	1.433	1.172	2.286	3.143	1.999	2.5
25	1.220	1.807	2.84	2.800	4.200	4.800	3.0
35	1.500	2.401	2.552	2.571	3.714	3.143	3.5
45	1.877	2.405	3.241	3.333	3.666	3.714	3.6
55	2.188	2.604	3.586	3.111	3.777	4.000	4.0
65	1.957	2.800	3.759	3.143	3.999	4.143	4.2

7. Conclusion

The purpose of this system is to be automatically control of the heat knob's power according to the input water level and input temperature. Fuzzy logic controlled water heater was accomplished to control power consumption .The fuzzy logic controller is better than fixed time controller because it makes use of linguistic variables rules and these linguistic variables can be naturally represented by fuzzy sets and logical connectives of these sets which are consistent with natural languages of human use. That is the advantages of fuzzy logic control system. This control system can extend to the bioler system of the plant.

8. References

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