Fuzzy Logic Project

Greenhouse Fuzzy Control System

Group 27

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Introduction - Helen Husca

This report describes the program written in Matlab which simulates the actions of a multi-input multi-output (MIMO) fuzzy control system for a greenhouse. The type of fuzzy controller used is the Mamdani controller. The operations of a Mamdani controller comprise of fuzzification, inference, composition, and defuzzification, which are demonstrated in an experimental simulation of the greenhouse problem.

Proposed Design for Fuzzy Logic Controller for a Greenhouse - Helen Husca

The goal is to design a fuzzy logic controller (FLC) for a greenhouse. As a start, we looked at an existing FLC for a greenhouse[1], which functioned as a suggestion of what such a fuzzy control system could consist of. The design of the greenhouse control system was broken into the subtasks of specifying the input and output variables, their universes of discourse, and their linguistic terms, each of which were assigned trapezoidal membership functions if the linguistic variables described the limits of the universe of discourse, and triangular membership functions otherwise. Following this, a suitable rule-base was constructed. The operations of the Mamdani controller were then demonstrated to give experimental results that were compared to the output of the simulation in Matlab, verifying the performance of the program.

The FLC consists of five inputs variables, Internal Temperature, External Temperature, Humidity, Light Level, and Soil Moisture, and three output variables, Sprinkler Setting, Heater Setting, and Ventilation Setting. Each of the input and output variables is a fuzzy set.

The universes of discourses for the linguistic variables Internal Temperature and External Temperature were chosen to be [-5, 40] °C, and their fuzzy partition is expressed through the linguistic terms Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH). VL and VH are assigned trapezoidal membership functions, and L, M, and H are assigned triangular membership functions.

Humidity and Soil Moisture have the universe of discourse [0, 100] %, and have five membership functions, two of which are trapezoidal for the linguistic terms VL and VH, and three triangular membership functions for L, M, and H.

The linguistic variable Light Level has a chosen universe of discourse of [0, 10000] lux, since light level can reach 0.0001 lux during the night and 10000 lux is considered daylight[2], and the corresponding linguistic terms are Night (N), Overcast (O), and Bright (B).

For the output variables Heater Setting and Ventilation Setting, the universe of discourse is [0, 100] %, the variables have the linguistic values VL, L, M, H, and VH.

[1] Aldababsa, Mahmoud (June 26, 2013). Green House. *MathWorks*. Retrieved October 10, 2019, from https://uk.mathworks.com/matlabcentral/fileexchange/42350-green-house

[2] Wang, L., Lin, W. B., and Lee, W. J. (March 15, 2009). Energy saving of green buildings using natural daylight. In *2009 IEEE/PES Power Systems Conference and Exposition* (pp. 1-7). IEEE.

The universe of discourse for the Sprinkler Setting is [100, 500] litres, and the linguistic terms VL, L, M, H, and VH represent its fuzzy partition.

In the rule-base, the rules for the Heater Setting are expressed as a cross product of Internal Temperature and Light Level, and for the Ventilation Setting as a cross product of Humidity and Light Level. Sprinkler Setting is determined only by Soil Moisture. The input linguistic variable External Temperature was used in the rule stating that if External Temperature is L or VL, then Heater Setting is H or VH respectively. While all the other rules in the rule-base have a weight of 1, this rule was given the weight of 0.2 to account for the fact that in cases of low external temperature, the setting of the heater needs to increase a small amount.

Experimental Simulation

The following section outlines the use of the components of the Mamdani-type FLC when the greenhouse fuzzy controller is given input variables.

1. Input - Helen Husca

We consider the case when the quantitative measurements of the input variables are as follows: Internal Temperature: 12°C, External Temperature: 2°C, Humidity: 60%, Light Level: 1000 lux, and Soil Moisture: 60%. For the FLC to generate decisions, these measurements must be turned to qualitative measurements through fuzzification.

2. Fuzzification - Helen Husca

The crisp input values are fuzzified into degrees of membership, the alpha-value, through the use of the membership functions.
For Internal Temperature, the relevant linguistic term is Low (Rule #12) and Medium (Rule #13), and applying the corresponding membership function for Medium Internal Temperature gives the alpha value of 0.2:

$$trimf\ M(Internal\ Temperature) = max\left(min\left(\frac{12-10}{20-10}, \frac{29-12}{29-20}\right), 0\right)$$

$$= max\left(min\left(\frac{2}{10}, \frac{17}{9}\right), 0\right) = 0.2$$

The other fuzzified input values were obtained in a similar manner:

	Internal Temperature	External Temperature	Humidity	Soil Moisture	Light Level
VL	0	0.8	0	0	N/A
L	0.2	0.25	0	0	N/A
M	0.2	0	0.33	0.33	N/A
H	0	0	0.33	0.33	N/A
VH	0	0	0	0	N/A
N	N/A	N/A	N/A	N/A	0
O	N/A	N/A	N/A	N/A	1
B	N/A	N/A	N/A	N/A	0

3. **Inference** - Josefa Kubitova

When we have the fuzzified linguistic input values, we can proceed to inference. Our rule base can be roughly split into 4 categories:

Rules 1-5 take Soil Moisture as antecedent, and Sprinkler Setting as the consequent as given in Table 1 in the appendix. In this example, rules 3 and 4 will fire. The antecedent of rule 3, Soil Moisture (M), is true to the degree of 0.33. Therefore, the alpha level cut to the output fuzzy set is applied at 0.33. Other rules with one antecedent are treated similarly.

Rules 6-20 take two antecedents, Internal Temperature and Light Level, affecting Heater Setting as shown in Table 2 in the appendix. These rules ensure a suitable heater setting depending on the time of day, as the ideal temperature for most plants drop at night time. Rules 12 and 13 will fire in this example. With rule 12, Internal Temperature (L) is true to the degree of 0.2, while Light Level (O) is true to the degree of 1.0. Since the MIN inference method is used, the alpha level cut to the output fuzzy set will be applied at min(0.2, 1.0) = 0.2. Other rules with two antecedents and the logical conjunction operation will be calculated in a similar manner.

Rules 21-35 also take two antecedents, Humidity and Light Level, and the consequent is Ventilation Setting as shown in Table 3 in the appendix. These rules ensure that the ventilation setting is higher during the day when plants need CO_2 for photosynthesis. Of these, rules 28 and 29 will fire in this example.

Finally, rules 36 and 37 take External Temperature and affect Heater Setting. They have a lowered weight (0.2 as opposed to 1 in the others). They increase the Heater Setting if External Temperature reaches an inappropriately low level, that is, VL or L. Both these rules fire in this example.

The results are as follows:

<table>
<tr><th>Rule</th><th colspan="2">Antecedent</th><th>Consequent</th></tr>
<tr><td>3</td><td colspan="2">IF Soil Moisture is M (0.33)</td><td>THEN Sprinkler Setting is M (0.33)</td></tr>
<tr><td>4</td><td colspan="2">IF Soil Moisture is H (0.33)</td><td>THEN Sprinkler Setting is L (0.33)</td></tr>
<tr><td>12</td><td>IF Internal Temperature is L (0.2)</td><td>AND Light Level is O (1)</td><td>THEN Heater Setting is M (0.2)</td></tr>
<tr><td>13</td><td>IF Internal Temperature is M (0.2)</td><td>AND Light Level is O (1)</td><td>THEN Heater Setting is M (0.2)</td></tr>
<tr><td>28</td><td>IF Humidity is M (0.33)</td><td>AND Light Level is O (1)</td><td>THEN Ventilation Setting is M (0.33)</td></tr>
<tr><td>29</td><td>IF Humidity is H (0.33)</td><td>AND Light Level is O (1)</td><td>THEN Ventilation Setting is H (0.33)</td></tr>
<tr><td>36</td><td colspan="2">IF External Temperature VL (0.8*0.2 = 0.16)</td><td>THEN Heater Setting is VH (0.16)</td></tr>
<tr><td>37</td><td colspan="2">IF External Temperature L (0.25*0.2 = 0.05)</td><td>THEN Heater Setting is H (0.05)</td></tr>
</table>

4. **Composition** - Josefa Kubitova

The only output fuzzy set in need of the MAX composition method is Heater Setting (M), for which the alpha-cut is 0.2 from rule 12, and 0.2 from rule 13. The union of these two fuzzy sets results in Heater Setting (M) = 0.2. After the results of composition, the fuzzy alpha-cut sets are:

- Sprinkler setting: Low (0.33) and Medium (0.33)
- Heater setting: Medium (0.2), High (0.05) and Very High (0.16)
- Ventilation setting: Medium (0.33) and High (0.33)

5. **Defuzzification** - Edvinas Teiserskis

For the defuzzification of outputs in the greenhouse system, Centre of Gravity, or centroid defuzzification, was used. This choice was mainly framed due to the nature of the system involved - in a greenhouse, changes in inputs very rarely happen at a rapid pace, and more depend on gradual changes over the period of a day. As such, the speed of the logic system does not have to be very high - a response time of under 5 minutes would still be considered reasonable, as the control acts upon gradually changing the state of the environment (e.g. how much water should the greenhouse receive in a day) rather than immediate actions. Therefore, we can take advantage of having the more developed results of centroid calculation (over mean of maxima calculation) without it impacting the performance of the implementation in a significant manner.

6. **Output** - Edvinas Teiserskis

Applying Centre of Gravity defuzzification, our current example gives us the following outputs:

- Sprinkler setting: 260 litres
- Heater setting: 66 %
- Ventilation setting: 60 %

A moderate amount of water is given to the greenhouse from the sprinkler, as the soil moisture was around medium-high. The ventilation is at a medium-high setting due to the medium-high level of humidity and overcast light level. The heater setting is hovering around high due to low-medium internal temperature, overcast light level, and the extra boost bumping it higher in reaction to the low external temperature.

Conclusion - Edvinas Teiserskis

With what we have shown above, we have designed a fuzzy logic controller for a greenhouse system. When applied using this example, and others not listed for space constraints, the system gave us reasonable results in regulating the heating, ventilation and irrigation of the greenhouse. The controller gives out the type of expected rough results, but was also able to fine-tune them in response to more marginal changes in the sensed input. As such, we believe that the application of fuzzy logic to this system was justified, as the added precision can act to respond to the smaller changes to use and conserve resources in a manner that a strict controller wouldn't be able to recognise and regulate.

Appendix

Soil Moisture				
VL	**L**	**M**	**H**	**VH**
VH	H	M	L	VL

Table 1: Sprinkler Setting

	Internal Temperature				
Light Level	**VL**	**L**	**M**	**H**	**VH**
N	H	M	L	VL	VL
O	H	M	M	L	VL
B	VH	H	M	L	VL

Table 2: Heater Setting

	Humidity				
Light Level	**VL**	**L**	**M**	**H**	**VH**
N	VL	L	M	H	VH
O	L	M	M	H	VH
B	M	H	H	VH	VH

Table 3: Ventilation Setting