CSU44001 - Fuzzy Logic

Fuzzy logic control system for an automated greenhouse

Group 8

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1. Introduction

We thought a good use of fuzzy logic would be for an automated smart greenhouse. There would be sensors for soil temperature and soil moisture, which would be out inputs. We would then use a fuzzy model to determine the amount of water outputted to the plants.
In our case we decided that the plants in our greenhouse would be carrots.

We have included files: team8_fuzzy_logic.fis and team8_simulink_model.slx with our report.

2. Description of Product

The product consists of a number of sensors used to measure soil moisture and soil temperature. The optimal ranges for these values would vary depending on the type of plant that the user wishes to grow, so for the purpose of this project we decided to use carrots as an example.

We created a Mamdani fuzzy controller using the Matlab Fuzzy Logic Designer. This made our development a lot quicker since we didn't have to program a controller from scratch and could use a nice graphical UI. Our controller receives the measurements of soil moisture and soil temperature as inputs, and outputs the amount of water that the plant needs in order to maintain an adequate soil moisture level so that the plant grows optimally.

In the case of carrots the optimal temperature is approximately 15-20 degrees celsius, so we modelled the membership functions of temperature accordingly. Soil moisture affects the shape and colour of the carrots, with dry conditions resulting in longer, thinner roots, and wet conditions giving the opposite and lighter colouration. We modelled the membership functions so that the adequate range is centered around 50, where 0 is the absence of water and 100 is complete saturation of the soil. [1]

If we were to change the type of the plant in the greenhouse, then only the membership functions of soil moisture and soil temperature would need to be tweaked. The rest of the fuzzy logic control system, along with the simulation would stay the same.

3. Knowledge Representation & Reasoning

3.1 Fuzzification

We had three fuzzy sets, two as input and one as output. For our inputs we had the linguistic variables 'Soil Temperature' and 'Soil Moisture', for the output we calculated the 'Amount of Water'.

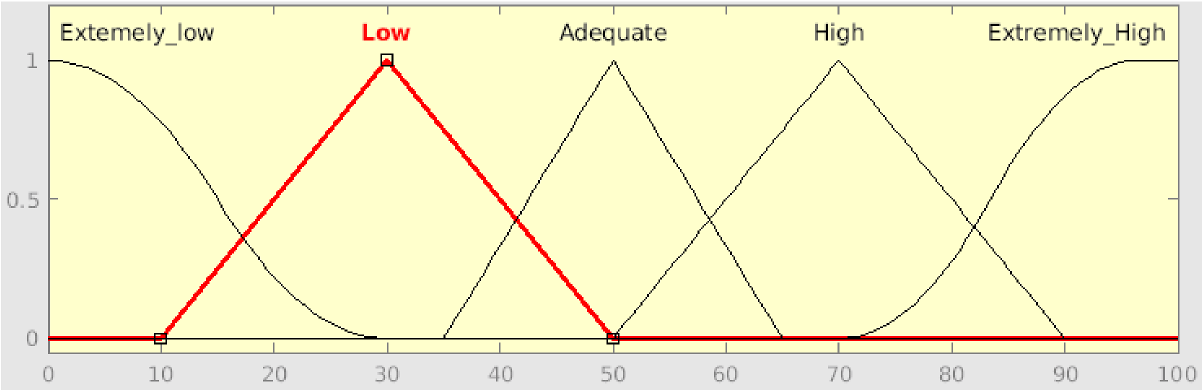

Figure 1: membership functions for ‘Soil Moisture’

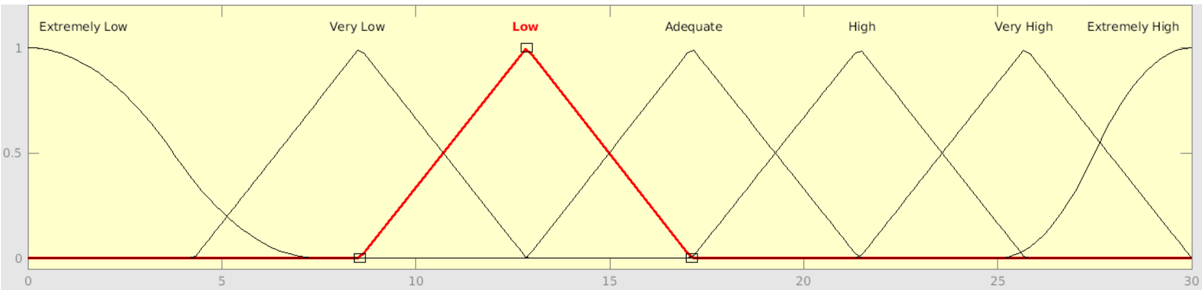

Figure 2: membership functions for ‘Soil Temperature’

‘Soil Temperature’ has elements {‘Extremely Low’, ‘Very Low’, ‘Low’, ‘Med’, ‘High’, ‘Very High’,‘Extremely High’’}, while ‘Soil Moisture’ has the elements {‘Extremely Low’, ‘Low’, ‘Adequate’, ‘High’, ‘Extremely High’}. We modelled our membership functions for our inputs as a series of triangular membership functions, except for the extremities, which we modelled as z-shaped membership functions.
Soil temperature's crisp value is in degrees celsius while soil moisture is on a scale of 0-100 based on a sensor measuring soil moisture with 0 being fully dry to 100 being fully wet.

3.2 Inference & Composition

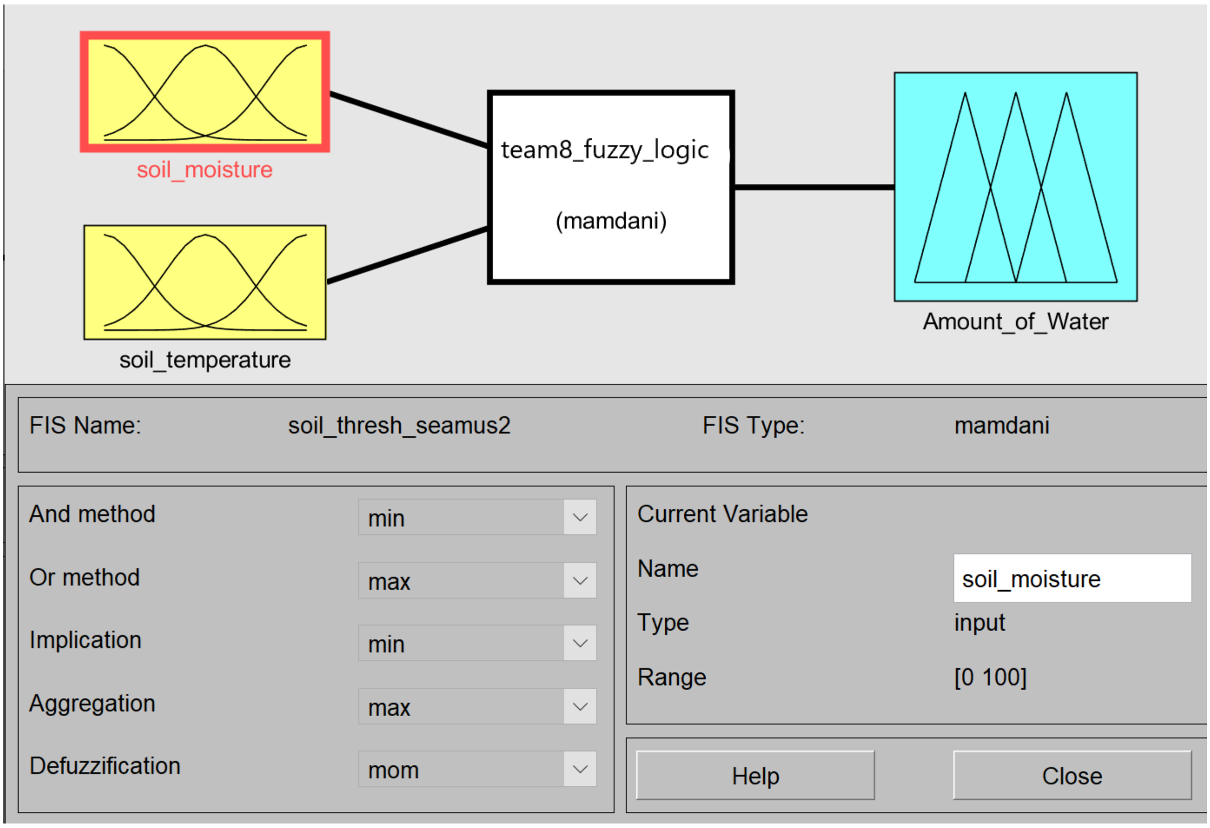

Figure 3: fuzzy logic control system

As seen above, we use the 'Min' inference method.

We use the 'Max' composition method.

Our rules:

1. If (soil_moisture is Extemely_low) and (soil_temperature is Extremely Low) then (Amount_of_Water is light) (1)
2. If (soil_moisture is Extemely_low) and (soil_temperature is Very Low) then (Amount_of_Water is light) (1)
3. If (soil_moisture is Extemely_low) and (soil_temperature is Low) then (Amount_of_Water is light) (1)
4. If (soil_moisture is Extemely_low) and (soil_temperature is Adequate) then (Amount_of_Water is medium) (1)
5. If (soil_moisture is Extemely_low) and (soil_temperature is High) then (Amount_of_Water is medium) (1)
6. If (soil_moisture is Extemely_low) and (soil_temperature is Very High) then (Amount_of_Water is large) (1)
7. If (soil_moisture is Extemely_low) and (soil_temperature is Extremely High) then (Amount_of_Water is huge) (1)
8. If (soil_moisture is Low) and (soil_temperature is Extremely Low) then (Amount_of_Water is light) (1)
9. If (soil_moisture is Low) and (soil_temperature is Very Low) then (Amount_of_Water is light) (1)
10. If (soil_moisture is Low) and (soil_temperature is Low) then (Amount_of_Water is light) (1)
11. If (soil_moisture is Low) and (soil_temperature is Adequate) then (Amount_of_Water is medium) (1)
12. If (soil_moisture is Low) and (soil_temperature is High) then (Amount_of_Water is medium) (1)
13. If (soil_moisture is Low) and (soil_temperature is Extremely High) then (Amount_of_Water is large) (1)
14. If (soil_moisture is Low) and (soil_temperature is Extremely High) then (Amount_of_Water is huge) (1)
15. If (soil_moisture is Low) and (soil_temperature is Very High) then (Amount_of_Water is large) (1)
16. If (soil_moisture is Adequate) and (soil_temperature is Extremely Low) then (Amount_of_Water is light) (1)
17. If (soil_moisture is Adequate) and (soil_temperature is Very Low) then (Amount_of_Water is light) (1)
18. If (soil_moisture is Adequate) and (soil_temperature is Low) then (Amount_of_Water is light) (1)
19. If (soil_moisture is Adequate) and (soil_temperature is Adequate) then (Amount_of_Water is medium) (1)
20. If (soil_moisture is Adequate) and (soil_temperature is High) then (Amount_of_Water is medium) (1)
21. If (soil_moisture is Adequate) and (soil_temperature is Very High) then (Amount_of_Water is medium) (1)
22. If (soil_moisture is Adequate) and (soil_temperature is Extremely High) then (Amount_of_Water is large) (1)

23. If (soil_moisture is High) and (soil_temperature is Extremely Low) then (Amount_of_Water is light) (1)
24. If (soil_moisture is High) and (soil_temperature is Very Low) then (Amount_of_Water is light) (1)
25. If (soil_moisture is High) and (soil_temperature is Low) then (Amount_of_Water is light) (1)
26. If (soil_moisture is High) and (soil_temperature is Adequate) then (Amount_of_Water is drain) (1)
27. If (soil_moisture is High) and (soil_temperature is High) then (Amount_of_Water is drain) (1)
28. If (soil_moisture is High) and (soil_temperature is Very High) then (Amount_of_Water is drain) (1)
29. If (soil_moisture is High) and (soil_temperature is Extremely High) then (Amount_of_Water is drain) (1)
30. If (soil_moisture is Extremely_High) and (soil_temperature is Low) then (Amount_of_Water is drain) (1)
31. If (soil_moisture is Extremely_High) and (soil_temperature is Adequate) then (Amount_of_Water is drain) (1)
32. If (soil_moisture is Extremely_High) and (soil_temperature is High) then (Amount_of_Water is drain) (1)
33. If (soil_moisture is Extremely_High) and (soil_temperature is Very Low) then (Amount_of_Water is drain) (1)
34. If (soil_moisture is Extremely_High) and (soil_temperature is Very High) then (Amount_of_Water is drain) (1)
35. If (soil_moisture is Extremely_High) and (soil_temperature is Extremely High) then (Amount_of_Water is drain) (1)
36. If (soil_moisture is Extremely_High) and (soil_temperature is Extremely Low) then (Amount_of_Water is drain) (1)

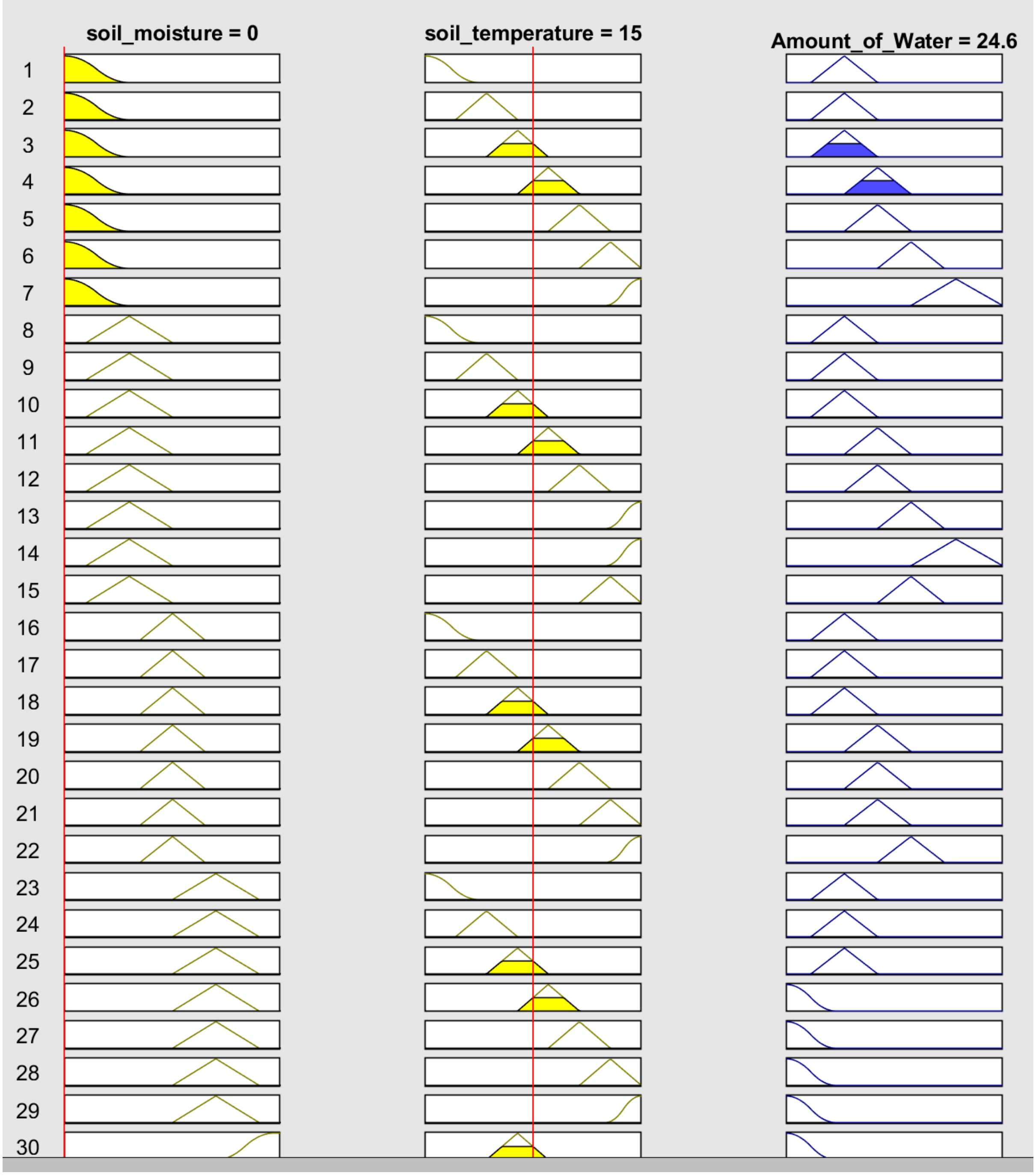

Figure 4: Our rules in action

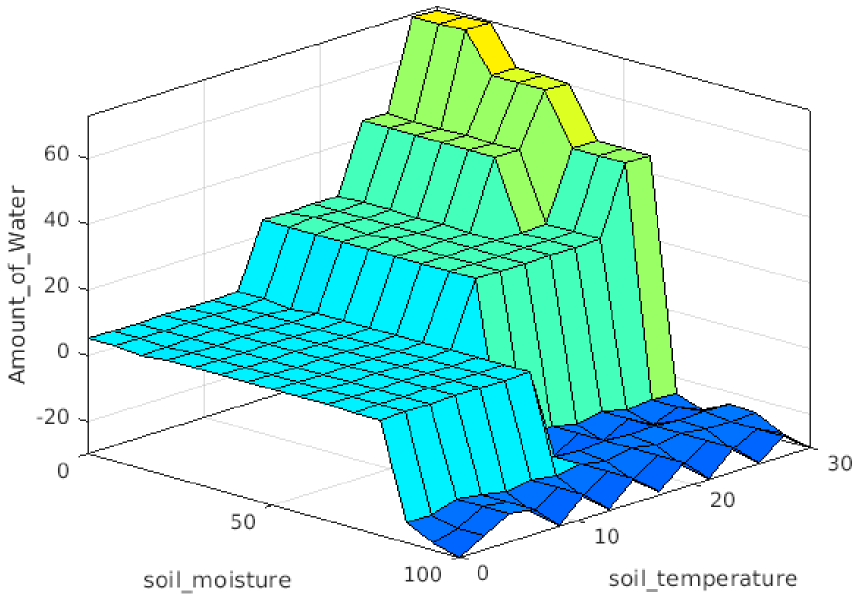

Figure 5: surface graph

3.3 Defuzzification

Initially we used COG for defuzzification, which returns the value of the center of area under the curve. Due to our increased familiarity with the MOM method, we decided to switch over to it. The MOM can be regarded as the point where balance is obtained on a curve.

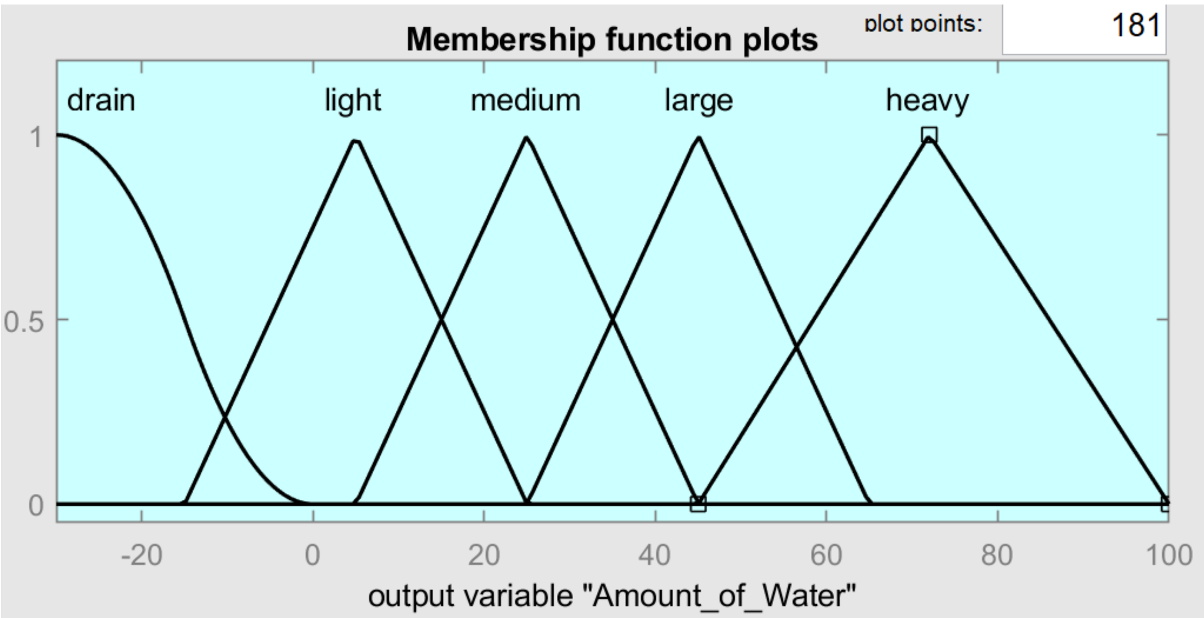

Figure 6: membership functions for ‘Amount of Water’

For our output, ‘Amount of Water’, we had elements {‘drain’, ‘light’, ‘medium’, ‘large’, ‘heavy’}, whose membership function was also modelled as a series of triangular membership functions except for drain, whose membership function was set high (1).

If the amount of water outputted is in the negative, this means we drain all the water from the soil. Our automated greenhouse would open holes under the soils basin to allow the water to drain out.

The crisp value after defuzzification of the amount of water is in mls.

4. Simulation

We used Simulink for modeling, simulating and analyzing our fuzzy logic systems.
Our simulation uses a signal generator to simulate various different soil temperatures. This is combined with the soil moisture through a mux and fed into our fuzzy logic controller. The soil moisture operates on a feedback system where the output of fuzzy logic system(the water added to plant) will have an effect on the soil’s moisture. Then the updated moisture will be used in the next iterations.

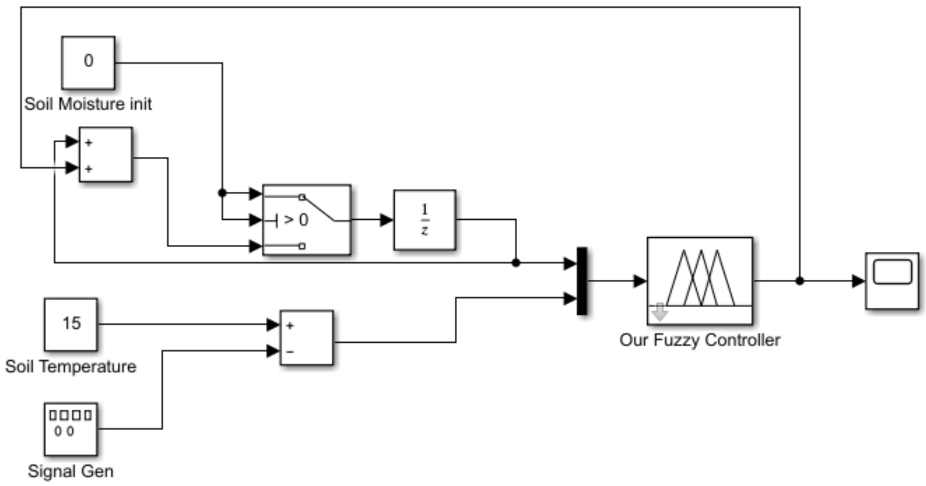

Figure 7: fuzzy logic simulation in simulink

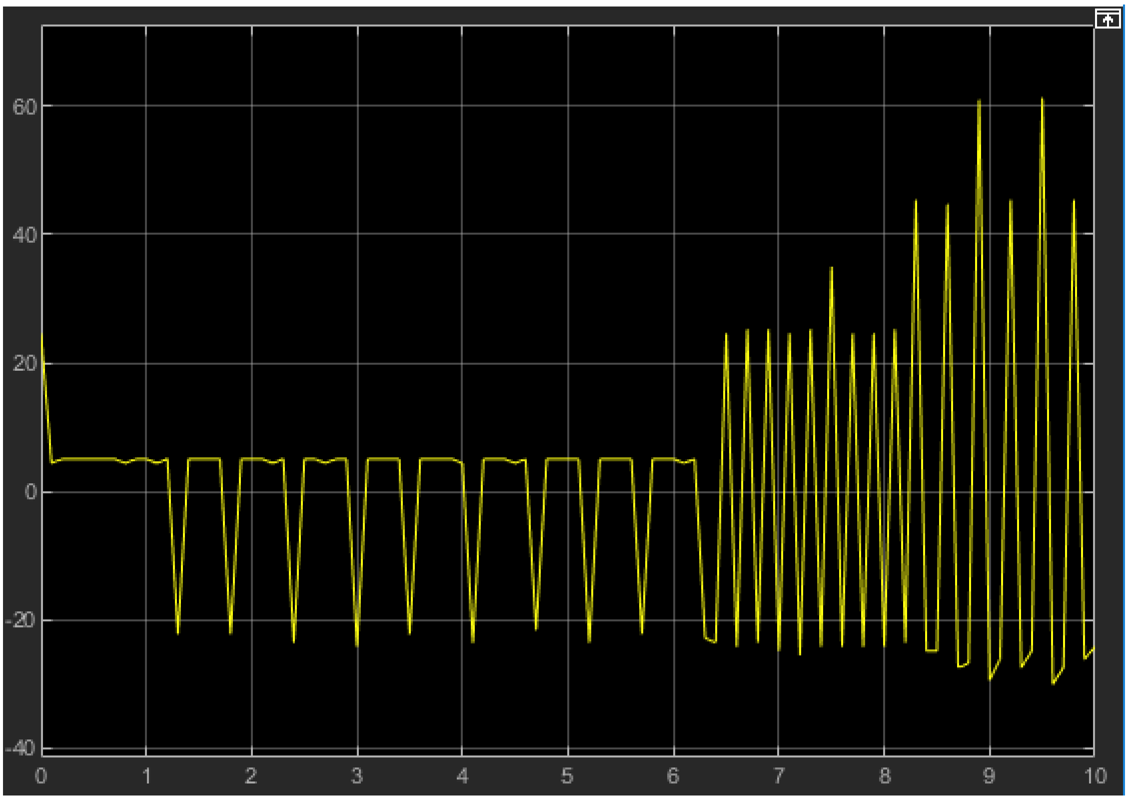

Figure 7: output from scope's reading of the value outputted from the fuzzy logic controller

5. Conclusion

Was the use of Fuzzy Logic justified? Yes, we believe so. Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. It doesn't matter exactly how much water a plant gets, for example the plant needs 52.3456ml of water today. It's more appropriate to think that because it's a hot day and our soil is dry, we should give the plant a large amount of water today. The use of sensors in the soil will enable us to constantly fire off rule if necessary and keep the soil temperature and soil moisture at optimum levels throughout the day. This fuzzy logic system would greatly benefit any greenhouse owner as it can reduce the amount of manual labour needed.

6. References

[1] https://www.farmersweekly.co.za/farm-basics/how-to-crop/growing-carrots/