KABARAK UNIVERSITY 4TH ANNUAL INTERNATIONAL CONFERENCE

GENERAL THEME:

ADDRESSING THE CHALLENGES FACING HUMANITY THROUGH RESEARCH AND INNOVATION

SUB THEME: **SYMPOSIUM 2**

Innovations and Engineering Technology for Sustainable Development

PAPER TITLE:

DESIGN OF A COMPUTER-BASED PSO-OPTIMIZED FLC MODEL FOR REGULATING GREENHOUSE CLIMATIC CONDITION.

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INTRODUCTION

A Greenhouse: is a building or complex in which plants are grown. It provides a climate-controlled environment for plants.

Greenhouse Modes of Operation

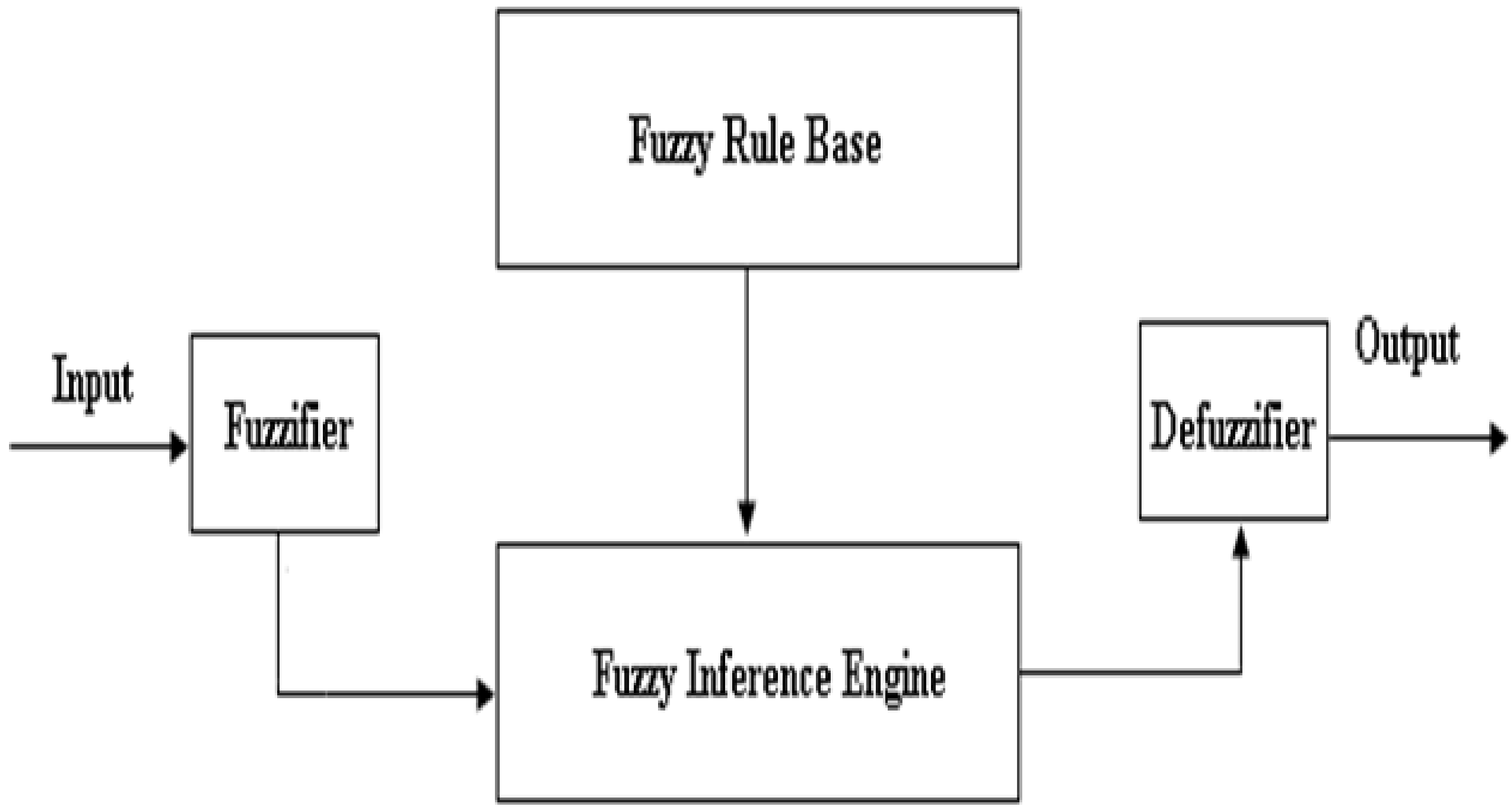
1. **Manual Operation**: Greenhouses are controlled manually with a lot of human intervention; this results to a lot of inefficiencies in resource utilization e.g. water, nutrients among others
2. **On/OFF Operation:** Control systems with on/off switching mechanism are used to control greenhouse climate by some growers.
   1. **Automated Operation:** Computer systems are used are used to monitor and control the greenhouse climatic parameters by use of Programmable Logic Devices (PLD) such as Fuzzy Logic Controllers (FLCs)

FUZZY LOGIC CONTROLLER (FLC)

The idea of fuzzy logic can be borrowed and implemented in greenhouses to serve as a logic of approximate human reasoning in greenhouse environments with an aim of optimizing controlled parameters.

FLC can have a continuous value between zero and one which are approximations. The basic structure of FLC consists of Fuzzification, Inference and Defuzzification.

BASIC STRUCTURE OF FLC



BASIC STRUCTURE OF FLC

- **Fuzzifier:** A Component which works on numerical data and converts it into a symbolic form through a data base

- **Fuzzy Rule Base:** A component which holds rules for decision-making.(Knowledge base)

- **Fuzzy Inference Engine:** A component that queries the knowledge base and fires the rule that matches a given scenario for a decision to be made.
- **Defuzzifier:** A component which provide symbolic answer which are later converted into a numerical data

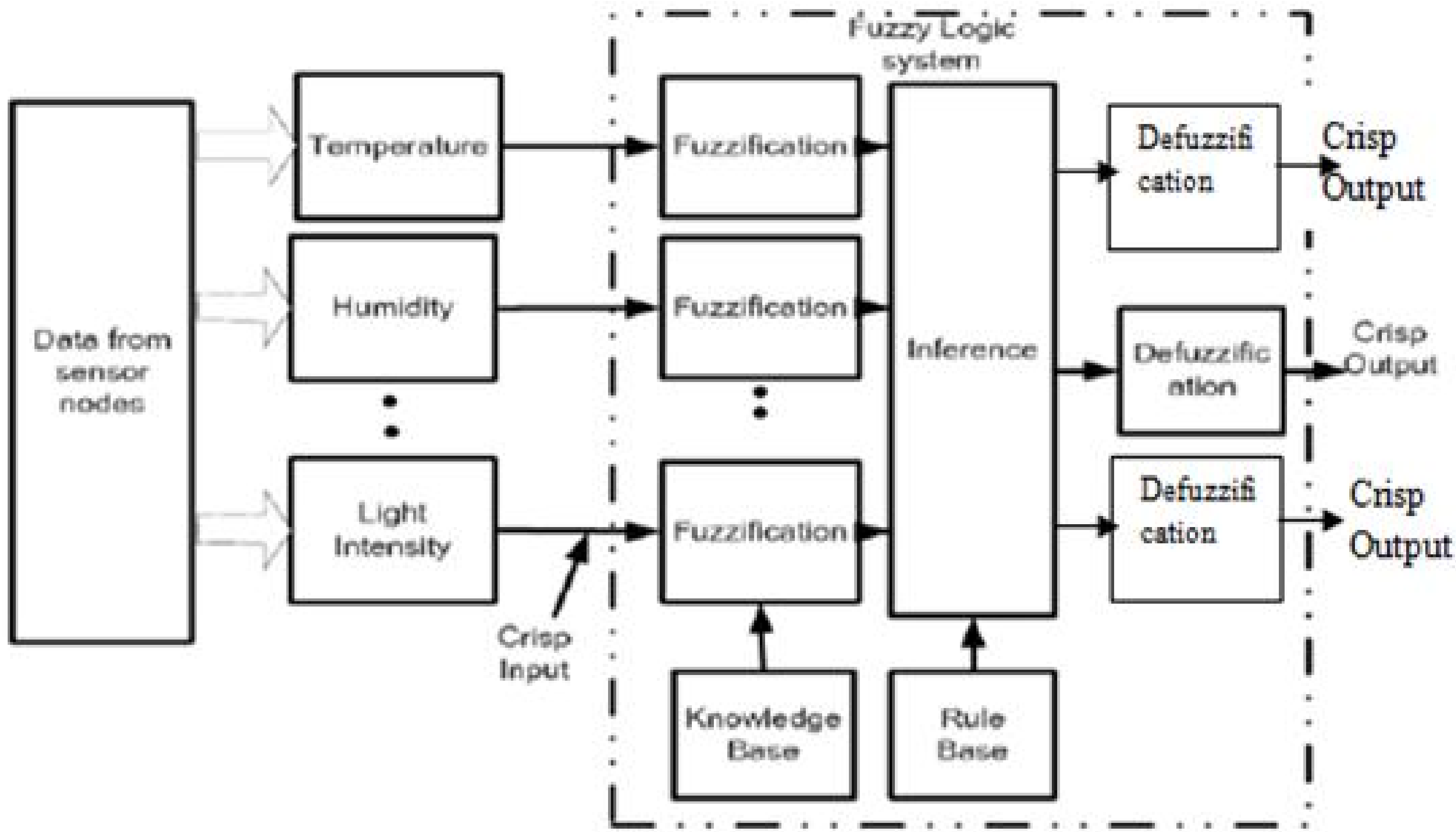
GREENHOUSE FUZZY LOGIC CONTROLLER

The realization of optimized FLC consisted of the following stages:

1) Choice of input and command variables,
2) Fuzzification,
3) Rule base creation,
4) Choice of the fuzzy inference,
5) Defuzzification.

GREENHOUSE FUZZY LOGIC CONTROLLER

In our greenhouse application, three inputs were provided, i.e. temperature, humidity and light intensity



CHOICE OF INPUT COMMAND VARIABLES

Green House Tomato Farming Climatic Parameters and Command Variables					
S/N	COMMAND VARIABLE	PARAMETER	MINMUM	MAXIMUM	UNITS
1.	**TEMP**	Temperature	15	25	Ċ
2.	**HUM**	Humidity	60	70	%
3.	**L_INT**	Light Intensity	375	650	Nanometer/lux

FUZZIFICATION

Each input is defined with several membership functions. i.e. Very low, Optimally low, optimally Medium, optimally High, very High.

In this research, triangular membership function was used.

The Fuzzy Logic Controller has three sets of membership functions for three inputs (temperature, humidity and light intensity) as illustrated below

MEMBERSHIP FUNCTIONS BEFORE OPTIMIZATION

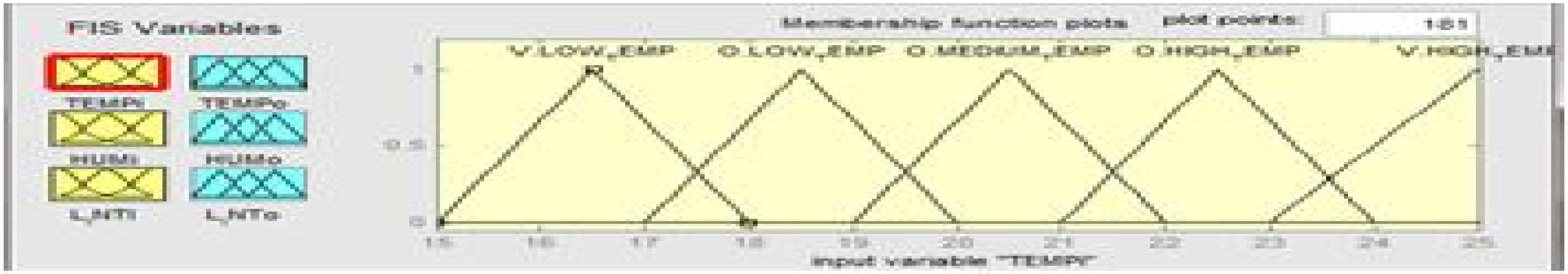


Figure: 3. Fuzzy Membership Functions for Temperature (TEMPi)

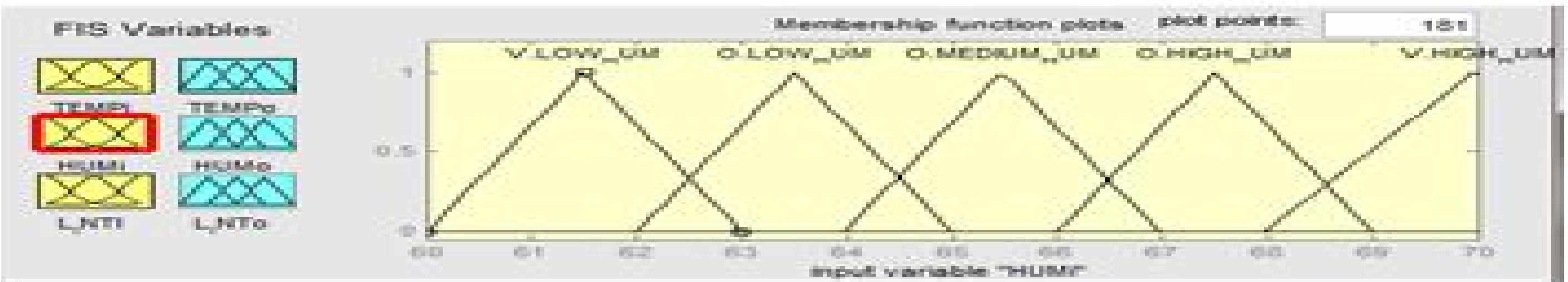


Figure: 4. Fuzzy Membership Functions for Humidity (HUMi)

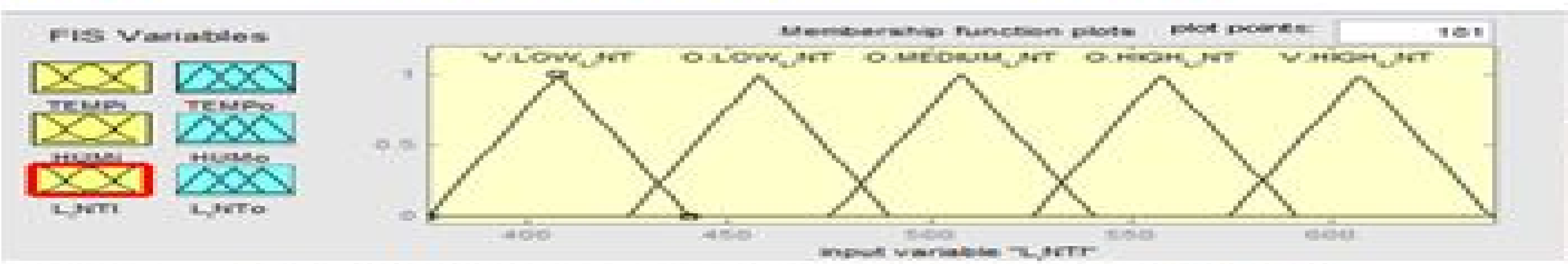


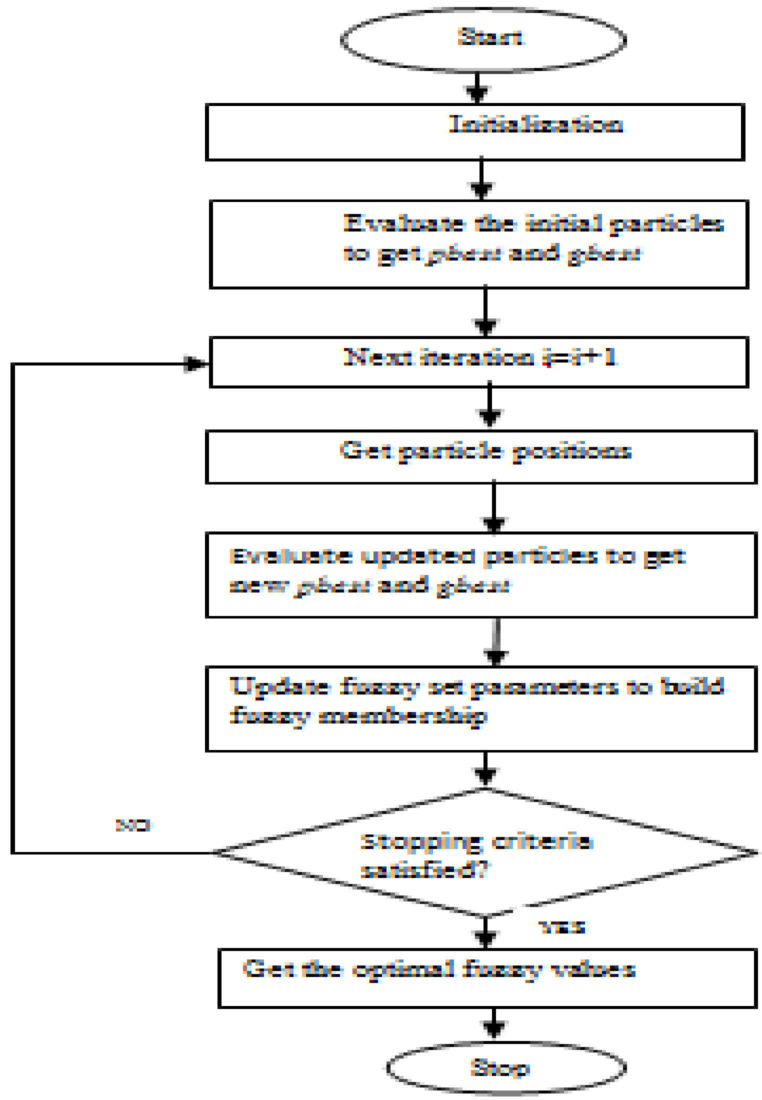
Figure: 5. Fuzzy Membership Functions for Light Intensity (L_INTi)

OPTIMIZATION OF FUZZY MEMBERSHIP FUNCTIONS USING PSO

The integration between PSO and fuzzy membership functions was as follows:

1. The parameters to be optimized are the centers, lefts and rights of each foot fuzzy membership function.
2. These parameters act as particles in the solution search space and looking for the global best fitness.
3. Initial parameters to be optimized are selected randomly.
4. After the parameters have been adjusted using PSO, these parameters will be used to check the performance of the fuzzy logic controller.
5. The process is repeated until a chosen stopping criteria is achieved or optimization method reaches the global best. The above algorithm is illustrated by the flowchart shown below.
6. After the optimal value is reached, PSO will produce new parameter values and make different shapes of the membership functions.

THE FLOWCHART OF PARTICLE SWARM OPTIMIZATION TO ADJUST FUZZY MEMBERSHIP FUNCTIONS



MEMBERSHIP FUNCTIONS AFTER OPTIMIZATION

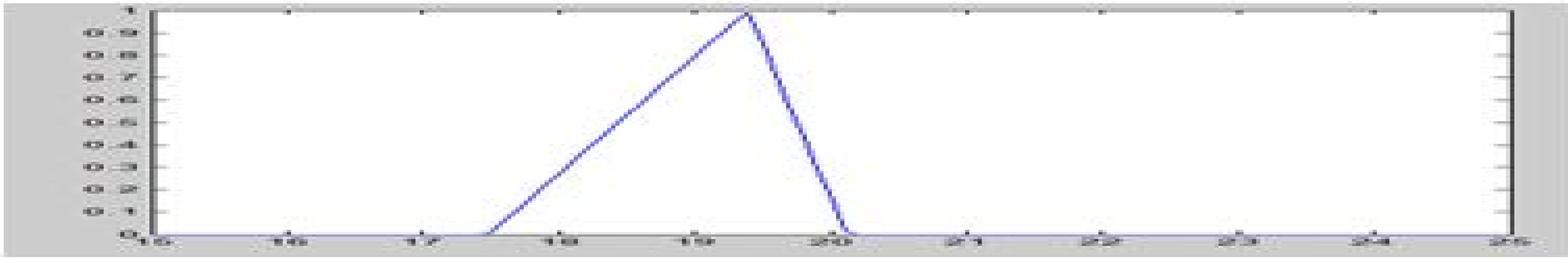


Figure: 7. Fuzzy Membership Functions for Temperature (TEMPi) after Optimization

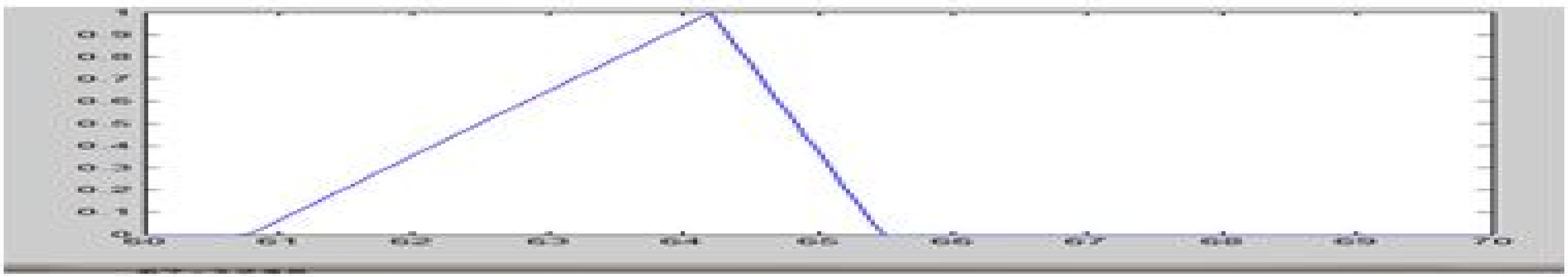


Figure: 8. Fuzzy Membership Functions for Humidity (HUMi) After Optimization

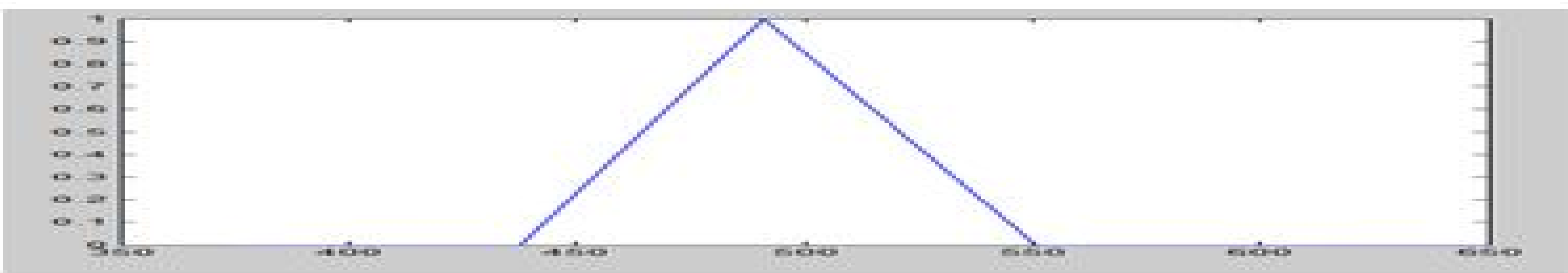


Figure: 9. Fuzzy Membership Functions for Light Intensity (L_INTi) after Optimization

DEVELOPING FUZZY RULES

The rules that govern the fuzzy logic controller, called if-then rules, are coded in MATLAB.

Fuzzy rules have been written the following form:

1. If (TEMPi is V.LOW_TEMP) and (HUMi is V.LOW_HUM) and (L_INTI is V.LOW_L_INT) then (TEMPo is FAN_OFF and HEATER_ON)(HUMo is HUMID_ON)(L_INTo is LCONTROLLER_OFF_FULL and BULB_ON)

2. If (TEMPi is O.HIGH_TEMP) and (HUMi is V.HIGH_HUM) and (L_INTI is O.HIGH_L_INT) then (TEMPo is FAN_ON_FAST and HEATER_OFF)(HUMo is HUMID_OFF)(L_INTo is LCONTROLLER _ON_NORMAL and BULB_OFF)

3. If (TEMPi is V.HIGH_TEMP) and (HUMi is V.HIGH_HUM) and (L_INTI is V.HIGH_L_INT) then (TEMPo is FAN_ON_HIGN and HEATER_OFF)(HUMo is HUMID_OFF)(L_INTo is LCONTROLLER _ON_FULL and BULB_OFF)

DEFUZZIFICATION

A defuzzifier compiles the information provided by each of the rules and makes a decision from this basis. In linguistic fuzzy models the defuzzification converts the resulted fuzzy sets defined by the Fuzzy Logic Controller (FLC) to the output of the model to a standard crisp signal.

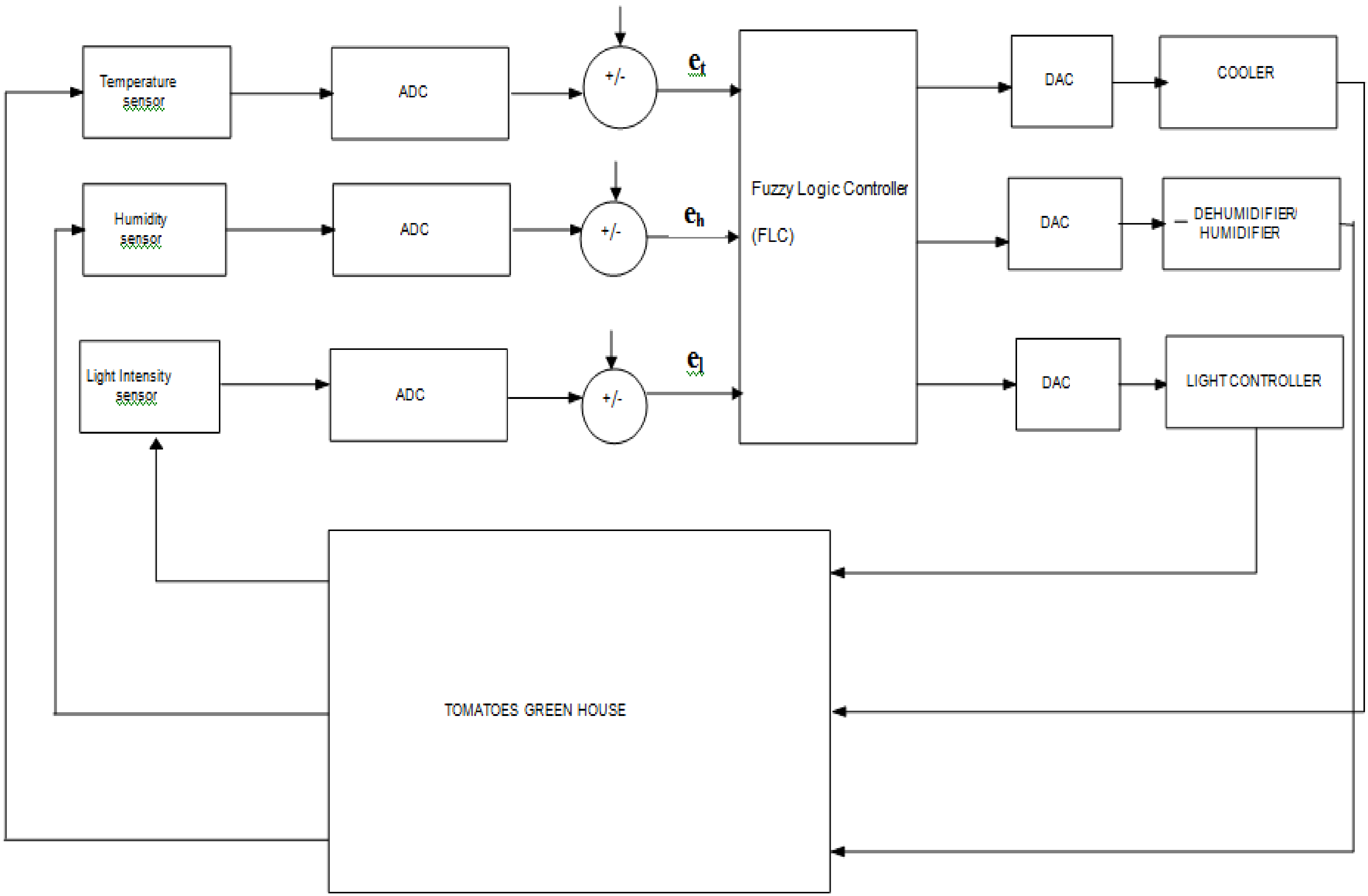
EXAMPLE:

If (TEMPi is V.LOW_TEMP) and (HUMi is V.LOW_HUM) and (L_INTI is V.LOW_L_INT) then (TEMPo is FAN_OFF and HEATER_ON)(HUMo is HUMID_ON)(L_INTo is LCONTROLLER_OFF_FULL and BULB_ON)

OUTPUT OF THE ABOVE

Fan is turned OFF and Heater is turned ON, humidifier is turned ON, Light _Controller is Turned OFF and bulb is turned ON

MODEL DESIGN



RESULTS AND CONCLUSIONS

Now we study behavior of the temperature and humidity for fan/heater and humidifier, respectively.

With a very low temperature (<=15°C) and very low humidity (<=60 %) the fan is off and heater is on. If temperature stays at this level and level humidity varies to very high still the fan is kept in the sleep mode. As temperature increases, the fan starts to work with its minimum speed. When temperatures go beyond optimum, the heater is turned off automatically.

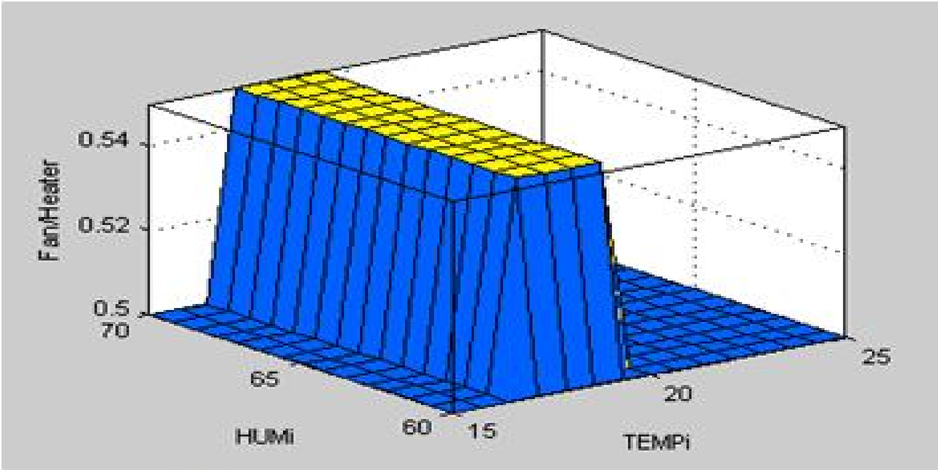
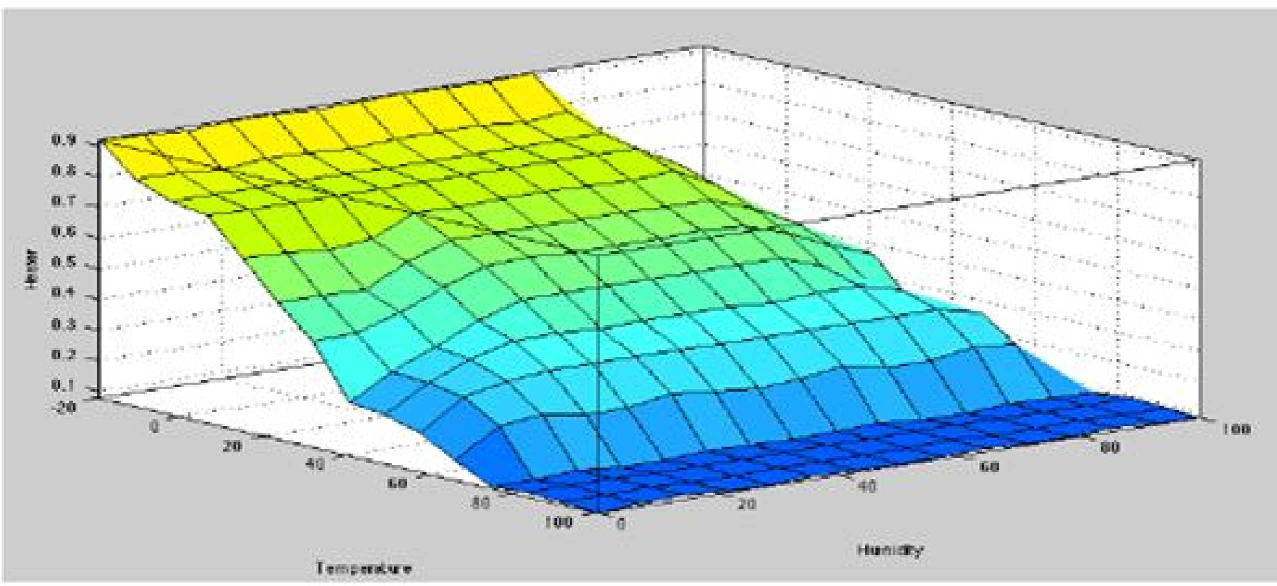


Figure: 15. Temperature and Humidity vs. Fan

Temperature and Humidity vs. Heater

If the humidity reaches to near 65 % that is in the range of medium level and the temperature is around 15 degrees then fan stops working again. After 20 degrees the fan works faster and faster, while the heater tends to off mode. If the temperature reaches to 25 degrees and above, then fan works at the maximum speed as the heater remains off.



Temperature and Humidity vs. Humidifier

The figure below shows temperature and humidity have a value of 20°C and 65 % respectively while light has a value of 500 lux. The figure clearly shows how the humidity is controlled by the humidifier/dehumidifier as the above parameters increases concurrently.

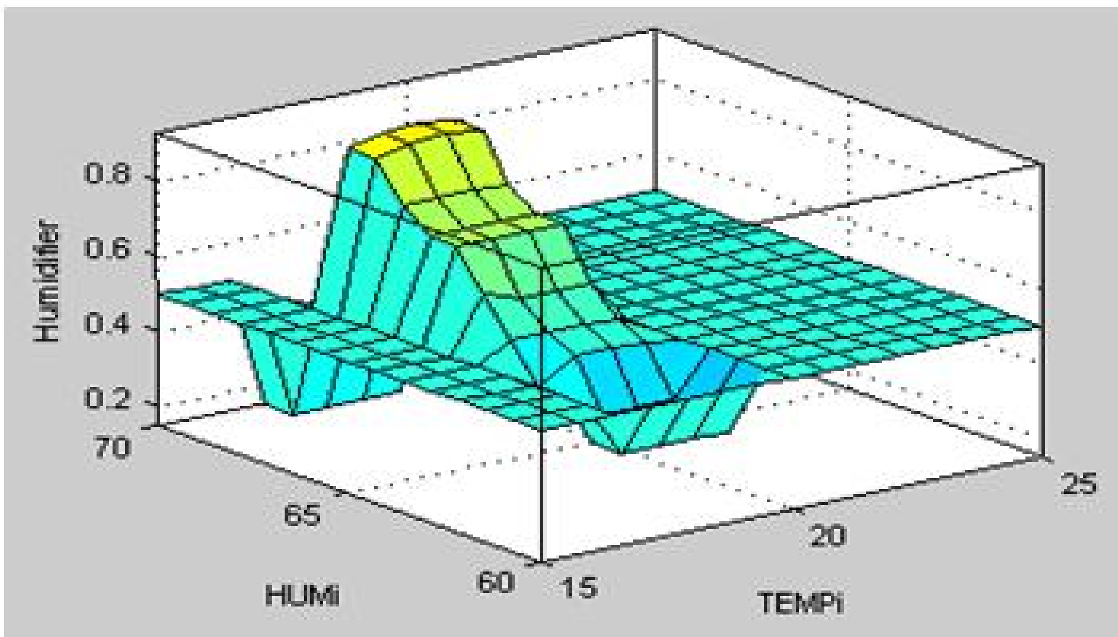


Figure: 17. Temperature and Humidity vs. Humidifier

Final Result for FLC

In our study, we defined 30 rules. For light, we considered the input to be 508 lux and the output was 0.5, i.e., the light control was varying from off to on.

The input for temperature and humidity was 20°C and 65 % respective and their outputs were 0.5 and 0.5 respectively;

Rule: 1, 6,15,20,25 and 30 indicate the extent the Fan was OFF in this region while Heater was ON.

Rule: 5, 10, 14, 19, 24 and 28 shows the Fan had more tendencies to go off, while Heater had tendencies to go ON.

On the other hand rule 11, 21, 22, 23, 24 and 25 show how to extend the fan's tendency to work with normal speed, while Heater was at sleep Mode.

Rule: 2, 7, 8, 12, 17, 22, and 29 show how to extend the fan's tendency to work with fast speed, while Heater was at sleep mode.

And finally, **Rule:** 3, 11, 16, 21 and 26 show how to extend the fan's tendency to work with high speed, while Heater was OFF.

A similar interplatation applies for both humidifier and light controller

Final Result for FLC

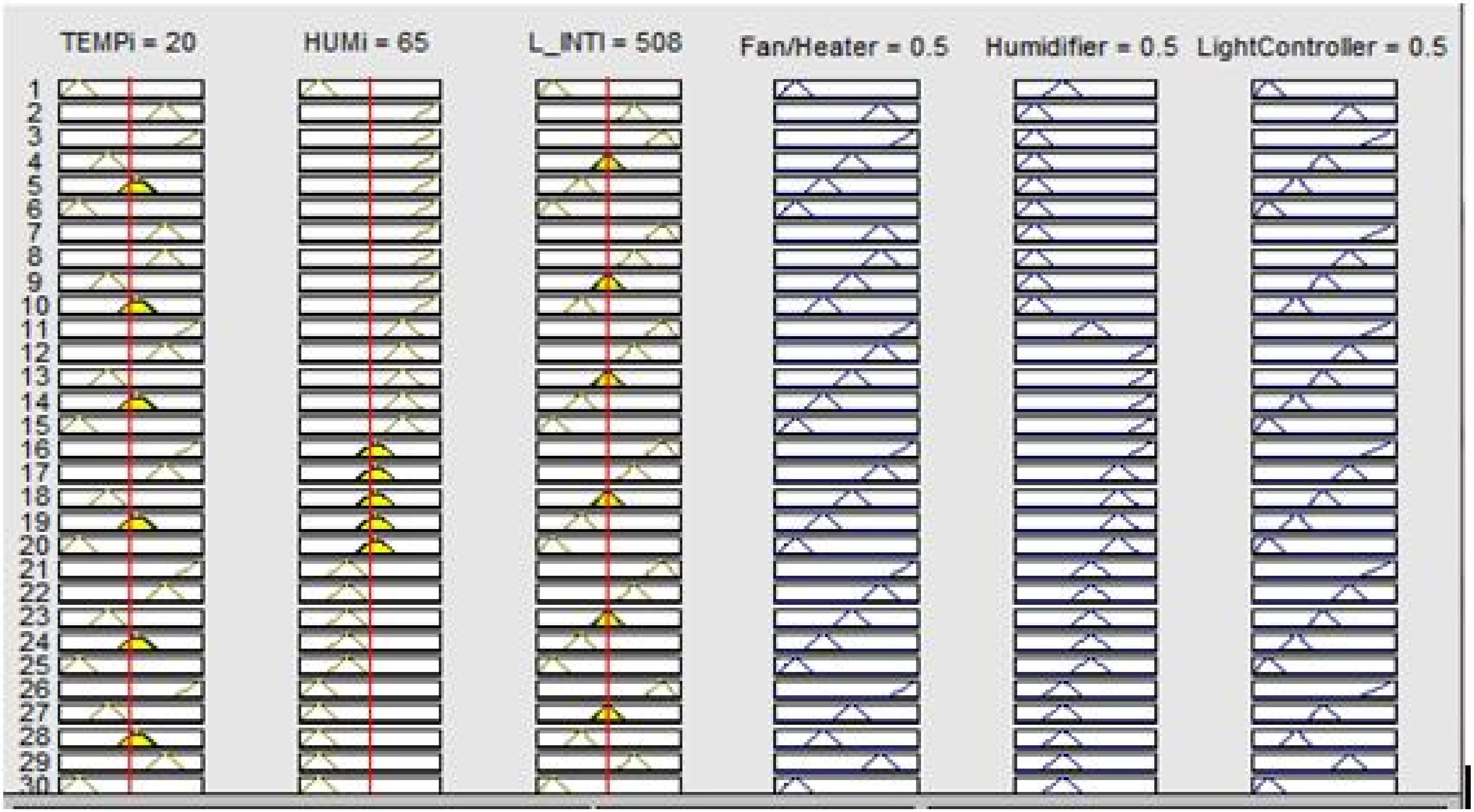


Figure: 18. Final Result for FLC in the above example

CONCLUSION

Fuzzy Logic Controller has a faster and a more accurate decision making capability compared to most computational systems. The researcher recommends the real implementation of the designed FPGA based fuzzy logic controller in tomato greenhouses, which will optimize both resources utilization and production as well provide conducive climate.

FURTHER WORK

This project has a great capacity for operation and modification of both hardware and software. However, we need to implement the design using Field Programmable Gate Array (FPGA) and write a VHDL program that is able to control the system using FPGA technology for the system to achieve better results.