Design of a Fuzzy Logic Controller for a Vent Fan and Growlight in a Tomato Growth Chamber

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Abstract - **In this paper, a fuzzy logic controller was design and develop to control the temperature, relative humidity and Carbon Dioxide (CO_2) inside the prototype tomato growth chamber. The model was develop to automatically adjust the inside parameters to obtain the optimum tomato plant environment condition. The growth chamber fuzzy logic controller was modeled using the MATLAB fuzzy logic tool box. In this research we design a fuzzy logic controller (FLC) to control the environment parameters in the growth chamber. In order to provide the most suitable conditions for the growth of the tomato plant and might minimize energy consumption.**

Keywords—fuzzy logic controller; growth chamber; temperature; humidity; CO_2 concentration, grow lights; vent fan; tomato;

I. INTRODUCTION

Growth Chambers are design to completely isolate the research from surrounding environment and provide complete control of the climate inside. The amount of light and temperature can be closely regulated, and some chambers offer humidity control and CO_2 enrichment options. This level of flexibility and control makes growth chambers indispensable for many researchers. [16] .Most experiments carried out in growth chambers do not aim on the full growth of the stem and plants. They are stopped after the plant starts to bud some flowers due to size restriction and light illumination. Some plants don't need carbohydrates for their vegetative growth and mainly distributed it to the fruits they bear. This type of plants are suitable in the growth chamber conditions. In many cases, tomato experiments are possible and ideal in growth chambers,

In growth chambers the values for the climate variables are base on how you want to condition the systems but in greenhouses without technical cooling the set points for the climate control are constraints.

The first strategy to do is to have a growth chamber with a strong limited light source. Nevertheless, these type of chambers are suitable for conducting experiments on tomato even for fruit production. Tomato is widely used as a model crop for fruit development but also for diverse physiological, cellular, biochemical, molecular, and genetic studies. It can be easily grown in green houses or growth chambers. Using appropriate cultivation techniques makes tomato a convenient model plant for researchers even for beginners. Temperature determines the speed of the phenological development while daily light integral and CO_2 concentration affect photosynthesis and biomass production. [1]

Many control strategies have been develop to optimize the greenhouse climate conditions such as Neural Network, Fuzzy Logic Controller (FLC), Adaptive Predictive Control, PID, Non Linear adaptive proportional -integral- derivative (PID) Control, Optimal Control and others. [2] In this paper the Fuzzy Logic Controller was design and develop to control the inside temperature, relative humidity and $C0_2$ by taking the input and output variables inside the growth chamber. The control algorithm was model using a growth chamber which have a controlled equipment such as exhaust vent fan and lights.

Fuzzy Logic is a decision system approach that works similarly to human logic. A useful technique that describes the input and output and provide conclusion from imprecise, ambiguous, vague input information. The fuzzy rule is similar to the use of ifthen, or and and, simply, fuzzy rule statement [3]. The mathematical concept behind the fuzzy are very simple and easy to understand unlike other control strategies. It can model non-linear functions of arbitrary complexity.

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Fuzzy system can be created to match any set of input-output data that is based on the experience of people who understand the system unlike Neural Networks which rely on training data and generate opaque, impenetrable model and PID who have difficulty in controlling complex task and much more complex compare to fuzzy.

A block diagram of FLC is shown in fig. 1, It consist of fuzzification, interference and defuzzification where in the input are put in the fuzzifier to activate the set of rules and the defuzzifier will produce the output. In the fuzzifier membership function values are assigned and the defuzzifier is used to convert the output fuzzy subset values. Mandani method is used in the fuzzy interference where in the set based of rules was established.

The fuzzy logic system will be used to determine the output of the growth chamber base on the crisp input.

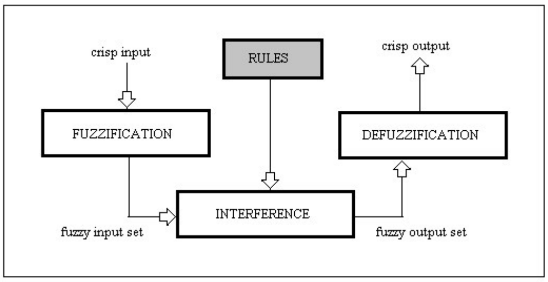

Fig. 1 FLC Block Diagram

II. MATERIALS AND METHOD

A. Growth Chambers

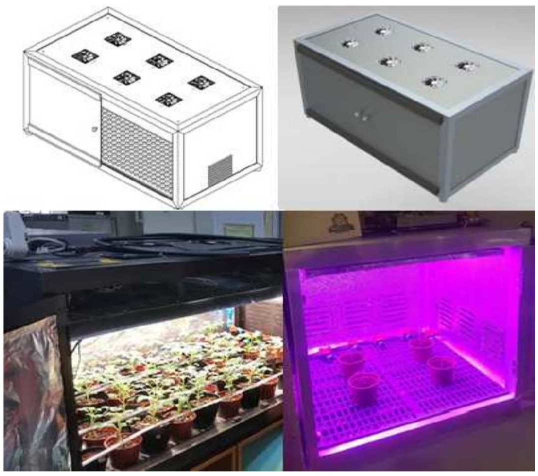

Fig. 2 Prototype Tomato Growth Chamber

The prototype tomato growth chamber was design and fabricated to test the effect of various grow lights such as fluorescent and different blue and red LED ratios. It has an approximate dimension of around 4'x2'x2' feet (**l**x**w**x**h**). The growth chamber is enclosed and has a sliding door to make sure that no other light passes thru it. The insides are covered with reflective material to make sure that the inside grow lights are evenly distributed to the tomato plant. It has a vent fan located at the top in order to minimize the hot temperature inside having a negative pressure effect in the chamber. Tomato seedlings are planted on individual pots where they will continue to grow in the container up to 6-8 weeks. Water and soil nutrients is applied by a drip irrigation system where the water is allowed to drip slowly in different small drip tubes directly on each pot however the prototype growth chamber is controlled manually. The lights are manually turn on for 8 hours and the vent fan system are operating all thru out the experiment. The quality of air in the growth chamber was recorded and monitor using a $C0_2$ monitoring device meter that shows the temperature, relative humidity and $C0_2$ concentration.

The purpose of this study was to design and develop a fuzzy system which can maintain and provide optimum plant environment condition for the growth of the plant and at the same time minimize the energy consumption of the prototype growth chamber. Controlling the various parameter and maintaining the desire condition of the chamber system. The output will be the exhaust vent fan and on/off lights. In the future studies drip irrigation will be study. Drip irrigation simplifies the supply of nutrient and saves time but it needs to be controlled and amount of supplied must be check to ensure the equal supply of nutrients solution [1].

B. Input Parameters

Temperature

In general tomato plant grow in temperature range of 10 to 35°C and survives up to 40°C and down to 0°C , However when the temperature does not match the radiation, abnormalities can occur [1]. Tomato Plants develop an estimated three leaves per week at a daily average temperature of 20°C. At around 6-8 weeks after flowering fruits will reach the ripe stage. The time in this development is negatively correlated with the temperature [1]. Plants may become thin, leaf thickness decreases and root growth is reduced resulting in plant deficiencies that make plants sensitive to diesease. It can lead to low production rate of carbohydrate bought in line with a low development rate.

This is possible in certain constraints by growing the plants at low temperature at the same time high temperature can cause the plant to dried up and shrink.

Relative Humidity

Relative Humidity of the air for the tomato plant is range between 65 to 75 percent and this is the optimal range for growth, flowering, and fruit set and fruit growth of tomato plant [1]. These condition can be realized and checked at the growth chamber and experimental greenhouse equipped with cooling, humidification and dehumidification equipment. Green houses are much more complicated compare to the small scale growth chamber. Below 30 percent relative humidity tomato plant still grows but not optimally in combination with high temperature. Plant dry matter content is increased and specific leaf area is decreased. Photosynthesis may decrease due to stomata closure at very high temperatures and low relative humidity. At a very low humidity growth is not inhibited but the ratio of nutrients to water uptake increases. However if the humidity is above 85 percent in combination with temperature of greater than 30°C are critical for fruit set. In addition high relative humidity favors fungi infestation and must be avoided by means of ventilating or if necessary by heating.

Carbon dioxide Concentration

Carbon dioxide $C0_2$ concentration effect on plants is quite simple as the CO_2 concentration increases the air photosynthesis and carbohydrate is enhanced. Raising the C02 concentration from the current ambient level of 400 to 1000 µmol increases the photosynthesis if tomato at approximately 30% [1]. This is used to compensate for the lack of radiation mainly in growth chamber. The problem is that the air exchange rates of the growth chamber and green house are usually below one which means the air inside is not replaced by an ambient air. Depending on the plant density and radiation, the CO_2 concentration may drop because it is not replenish outside. In green houses it values down to 150 µmol and in growth chamber even below 100 µmol. increasing the air exchange rate by pumping air inside the chamber is one option however the climate control device may not work properly. Monitoring of the CO_2 concentration in the plants environment is necessary.

III. RESULTS AND DISCUSSION

MATLAB SIMULATION

The membership function and simulation have been done using the fuzzy logic controller as shown in figure Three inputs and outputs have been define. The input parameter are temperature, relative humidity and CO2 concentration. The growth chamber have two outputs which is the exhaust vent fan and the fluorescent light.

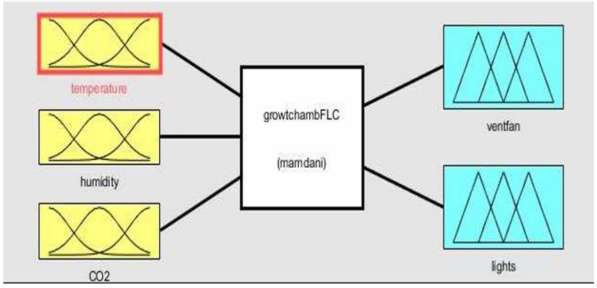

Fig. 3 Input and Output Membership Function

Temperature ranges values from 0 to 40°C and subdivided into 5 regions having the good region as the ideal optimal temperature condition range somewhere between 10 to 35°C. The tomato plant can survive this wide range of temperature but having the temperature at the good region is ideal.

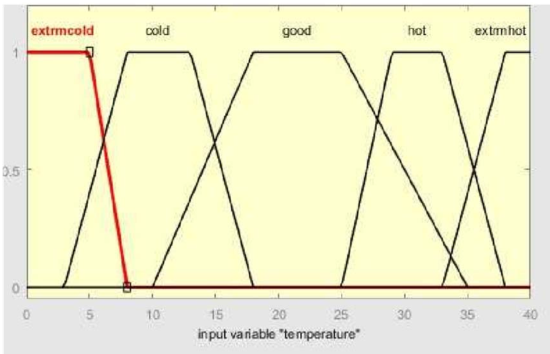

Fig. 4 Input temperature ranges

Humidity Level is divided into 3 regions, the dry, acceptable and the moist. Dry zone ranges from 0 to 40°C where it might hinder the growth of the plant and fruit bearing capabilities due to lack of moisture. Acceptable or the ideal relative humidity zone range is somewhere areound 30 to 90 percent and the moist ranges from 80 to 100 percent where fungi contamination might occur.

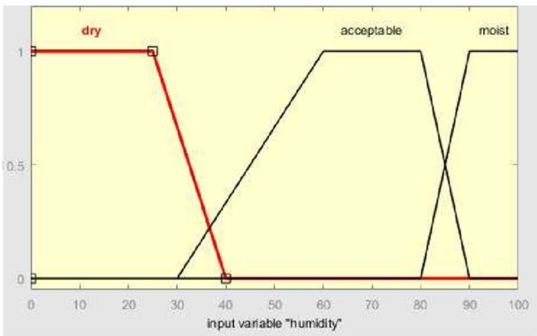

Fig. 5 Input relative humidity ranges

As Carbon dioxide concentration increase the photosynthesis and carbohydrate production also increases and it is subdivided into 3 regions. The ideal CO_2 concentration or the good region is around 200 - 1500 µmol.

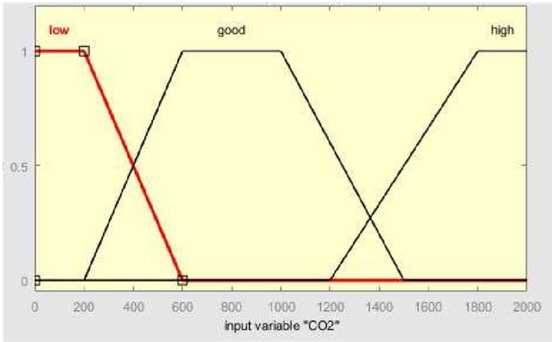

Fig. 6 Input Carbon Dioxide Concentration ranges

We have consider two output as the exhaust vent fan and the lights that will balance the temperature, humidity and $C0_2$ concentration. The vent fan is divided into 4 regions zero, low, medium, and high. The prototype growth chamber is consist of 6 fans. At zero region no fan will run at all, at low region only 2 fans will turn on, at medium 4 fans will turn on and at high all the fans will turn on.

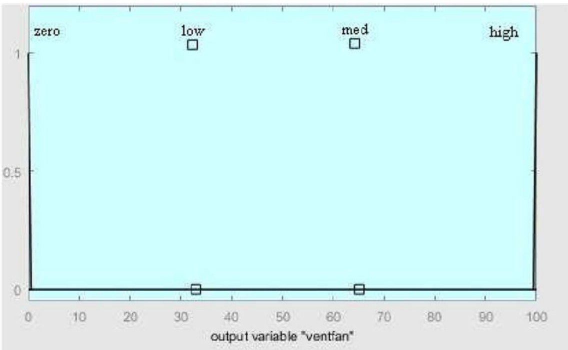

Fig. 7 Output Vent Fan

The lights is set to run for around 8 to 10 hours and necessary for the plant photosynthesis and carbohydrate products. The output of the light will be just turning on and off which will increase or lessen the heat in the growth chamber. Note that graph on this output variable is just on and off which is equivalent to 1 or 0 refer on figure 8 & 9.

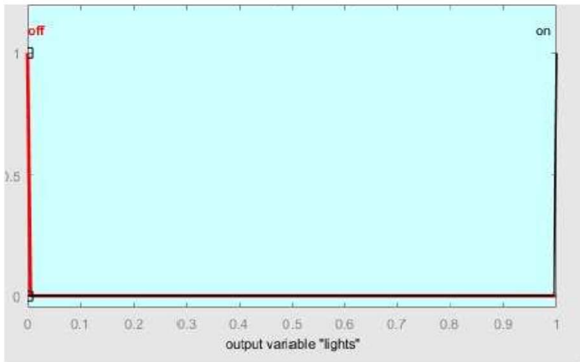

Fig. 8 Output Lights on/off

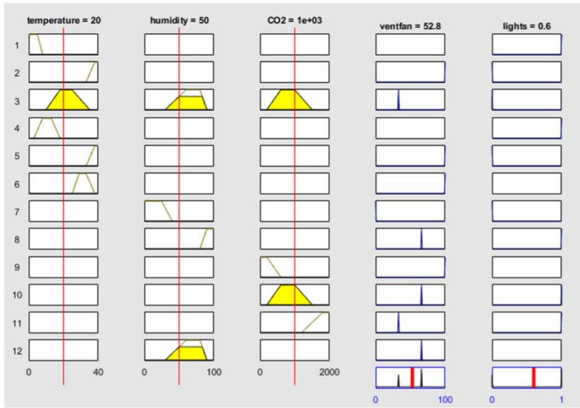

Fig. 9 Fuzzy Logic Controller

A total of 12 fuzzy logic rule was develop in order for the output vent fan and lights to function. At extreme high temperature the vent fan will function at high mode turning all the fans on and the lights will turn off reducing the heat from the light. Low temperature will make the lights turn on heating the chamber. Low humidity will turn off the lights and fan because the chamber condition is too dry. Having high humidity will turn on the lights and put the exhaust vent fan on medium setting. If the $C0_2$ concentration is low the vent fan will turn on high mode allowing ambient air to enter at the bottom while having a high $C0_2$ concentration will turn the lights on and fan in to low mode in order for the tomato plant have a good photosynthesis and carbohydrate production.

The fuzzy rule here are just assumptions on how the outputs will function but may change as the sample and growth chamber is further studied.

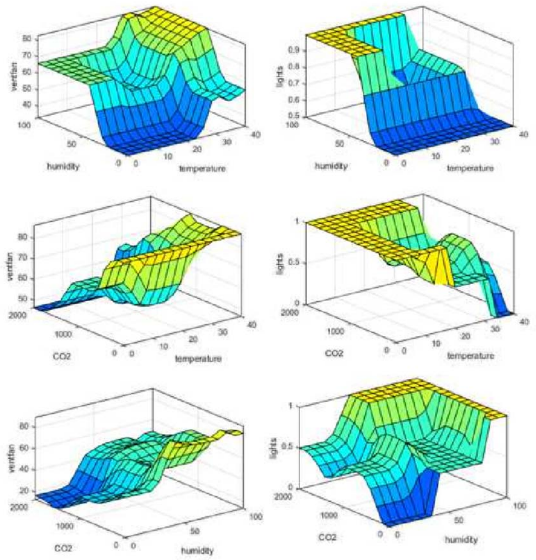

Fig. 10 Surface Viewer

Figure 10 shows the three dimensional curve that represents the temperature, humidity, and carbon dioxide concentration plotted against the ouput for vent fan and lights. The surface curve shows two-input and one output case per curve. It shows on the graph that the output parameters are dependent on the input as the rules are establish that way but may change as further studies are needed for the dependency of the input and output. Additional output may be incorporated in the future studies as mention on the first part that the drip irrigation is not yet consider in this study.

IV. CONCLUSION

A simplified dynamic model of a Fuzzy Logic Controller for tomato growth chamber was design and develop using a MATLAB Fuzzy Toolbox. The fuzzy logic system is design to maintain and control suitable environment conditions for the tomato plant that might aid and improve the quality of growth at the same time reduce energy cost of the growth chamber. Further studies will be applied in the fuzzy logic controller such as MATLAB simulink simulation and actual experimentation and application in the prototype tomato growth chamber.

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