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Control Difuso de una Cámara de Germinación para Hidroponía

Fuzzy Control of a Germination Chamber for Hydroponics

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Resumen

Este estudio presenta una cámara de germinación construida para un sistema hidropónico de agua provisto de un controlador basado en lógica difusa. El sistema fue construido sobre la base de una plataforma electrónica Arduino, donde residen los sistemas de programas de control y telemetría difusos. Además, todos los datos de los sensores se almacenan para futuros estudios. El sistema de telemetría envía los datos obtenidos por el sistema a dos ordenadores, uno a través de un USB (*Universal Serial Bas*) y el otro a través de BT (*Bluetooth*). Todos los datos se almacenan en discos virtuales. Los resultados muestran que la cámara de germinación construida tiene mejor rendimiento que el sistema de raíz flotante convencional.

Palabras clave: Hidroponía; Lógica difusa; *Lactuca sativa* L. (lechuga); Control automático; Arduino.

Abstract

This study presents a germination chamber built for a water hydroponic system provided with a fuzzy logic based controller. The system was built based on an Arduino electronics platform where the fuzzy control program and telemetry systems lie. Also, all data from sensors are stored for future studies. The telemetry system sends the data obtained by the embedded system to two computers, one conected via a USB (Universal Serial Bus) and the other conected via BT (Bluetooth). In both cases data are stored in virtual disks. The results show that the germination chamber built has better performance than the conventional floating root system.

Keywords: Hydroponics; Fuzzy logic; *Lactuca sativa* L. (lettuce); Automatic control; Arduino.

Introduction

Hydroponic system consists of growing plants in a water and nutrient solution without soil. The requirements for plant growth include root humidity and stable temperature, good aeration, the required nutrient salts and their availability in the correct proportions.

By providing the exact nutrients that plants need, they will grow faster and bigger.

The most used hydroponic systems can be classified into [1, 2, 3]:

a) Solid substrate: a strong base is used as a support for plant roots, such as rice husk, peat or other organic or inorganic element that serves as support for roots. In this case the nutrient is distributed through a dripping or spraying system [4,5].

b) Floating Root Plants grow on an expanded polystyrene (EPS) floating plate in a bowl of nutrients [4].

The NFT (Nutrient Film Technique) system is a hydroponic cultivation technique in which plants grow with their roots submerged in a channel. It was implemented by Allen Cooper in 1970 [2, 6, 7, 8, 9, 10, 11].

For seed germination, in most known systems of hydroponic planting, indirect planting is used. This means that the seeds are sown in containers of the floating root type. When the seedlings reach enough size, they are transplanted to the NTF hydroponic system where they develop until harvest.

The environmental conditions for germination and seedling growth are critical for the successful development and good crop production. Thus, a system of measurement and control of environmental variables based on fuzzy logic was developed.

The fuzzy set theory initiated by Zadeh [12], as opposed to mathematical logic using linguistic terms, allows easy interpretation. A branch of fuzzy logic is the study of control systems [13]. Fuzzy controllers have the advantage of greater interpretability to be designed according to an expert in a particular subject. For this purpose, it is possible to use linguistic labels for intervening variables as "very low", "low", "high", "very high". Moreover, the fuzzy set defining the variables has flexible membership values. These characteristics result in a better response of the fuzzy system controls [14, 15] than conventional reactive systems.

The aim of this work was to develop a control system for germination chambers based on the fuzzy logic theory.

Materials and Methods

Germination chamber construction

The germination chamber (Figure 1) was constructed using a plastic top cover on which a hygrometer and temperatures sensors were placed inside and outside. As a source of artificial light, low consumption lamps and incandescent lamps were used to provide heat when the ambient temperature was very low. Also a fan providing forced air flow, and a webcam type of camera to record the process, were incorporated to the system.

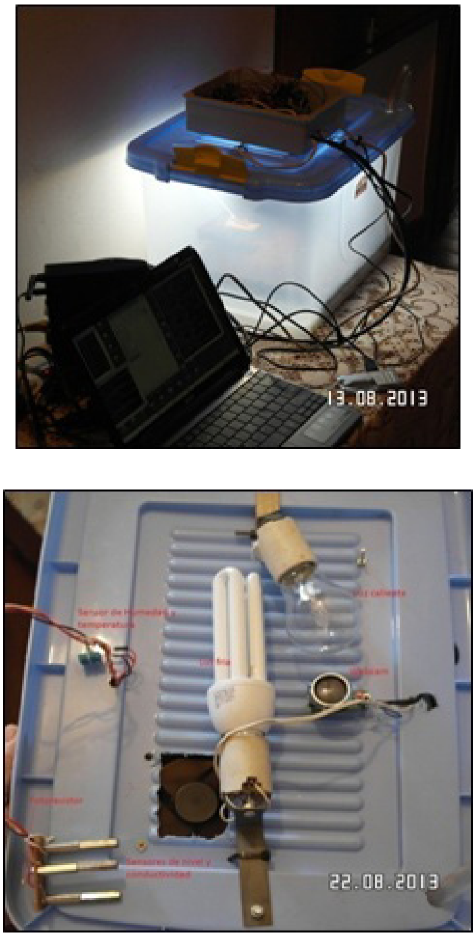


Figure 1: Germination chamber.

To control a webcam in the chamber the OpenCV library was used. This libray is allowed license for academic and commercial use under a BSD (Berkeley Software Distribution) license. By means of a software in a notebook, two daily photos were taken and stored in a virtual disk to perform an optical analysis of the evolution of seedlings and to identify nutritional deficiencies in the different stages of their development [16]. Future work will include an optical analysis technique to determinate the growth rate.

Fuzzy Control System

A Sugeno type fuzzy control was used because a defuzzification stage was not required and thus the code is less heavy regarding programming lines.

Figure 2 shows the block diagram of the control system. An Arduino Mega 2560 was used as the processing unit. It consists of a hardware platform based on a processor Atmel ATmega 8U2 type which has low cost at local market.

Peripherals consist of a real-time RTC clock; a power plate with optocouplers provides galvanic isolation between the digital control system and the power devices: pump nutrients, warm light, cool light and fan. Besides, an acquisition system was implemented using an Arduino to capture sensor data: liquid level, light intensity, temperature and humidity inside and outside.

The telemetry system comprises two telecommunication routes: the first through a physical USB connection to a PC, and the second through a wireless connection via Bluetooth to another PC, one as well as the other with internet connectivity. Both PC dropboxes update their data in virtual disks.

A two-way communication system is used in the event of failure of either of them. When this situation occurs, data storage allows for the active path.

Design of Fuzzy Controller

Based on the advice of an expert in plant biology, the species *Lactuca sativa* L. (lettuce) was selected because there are plenty of studies of this type of culture for this species [17,18] . Fuzzy input (Figure 3) and output sets were defined as well as the universe of discourse of each variable (U_T ° u_h, U_V, U_LC) . Also, low, medium and high linguistic labels for temperature and humidity were set: off 50% and 100% for the fan control and on-off for hot light.

Input variables

Temperature:

U_ T ° [-5, 60]
low [-5, -5, 10, 18]
mean [16, 20, 24]
high [22, 30, 60, 60]

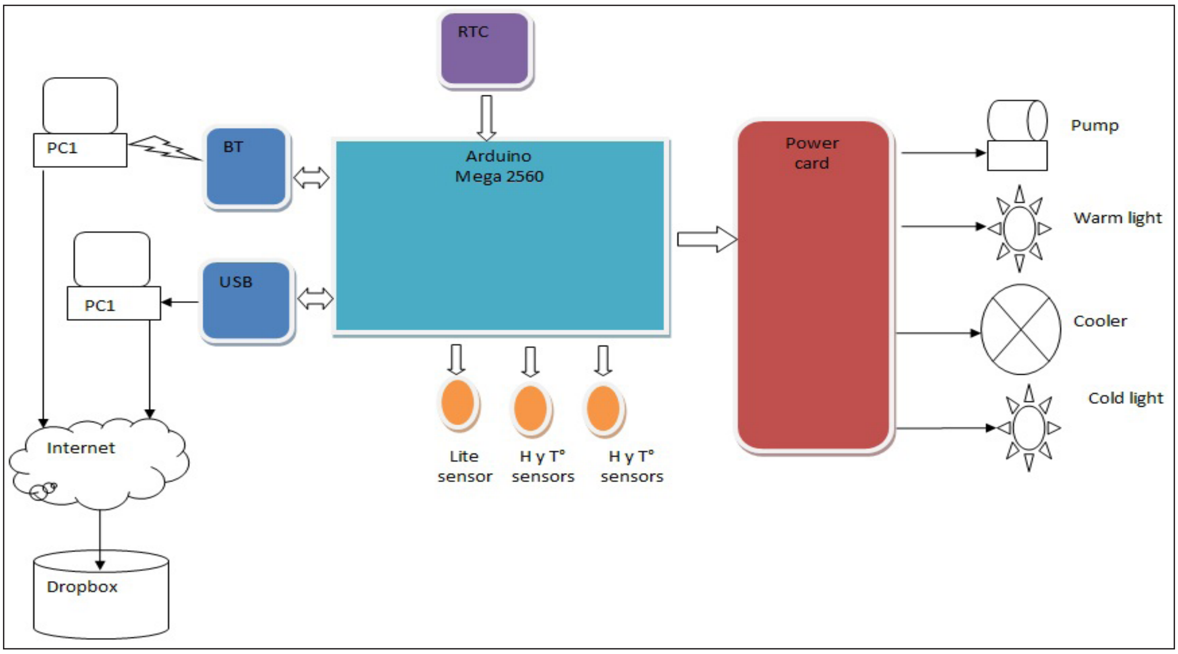


Figure 2: Block diagram of the fuzzy control system.

Humidity

U_h [0, 100]
Low [0, 0, 40, 60]
mean [40, 60, 80]
high [60, 80, 100, 100]

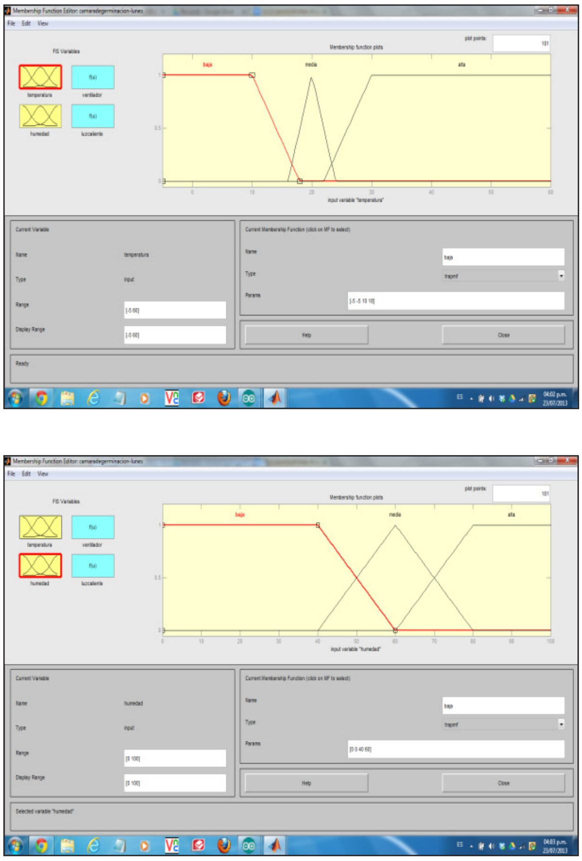


Figure 3: Fuzzy sets of the input variables of temperature and humidity.

Output variables:

Fan

U_V [0, 100]
off 0
50% 0.5
100% 1

Warm Light

U_LC [0, 1]
Power 1
off 0

Fuzzy Rules

1. If (temperature is low) and (humidity is low) then (fan is off) (cold light is on) (Warm Light is on) (1)

2. If (temperature is low) and (humidity is average) then (fan is off) (cold light is on) (Warm Light is on) (1)

3. If (temperature is low) and (humidity is high) then (fan is 50%) (cold light is on) (Warm Light is on) (1)

4. If (temperature is low) and (humidity is medium) then (fan is 100%) (cold light is on) (Warm Light is on) (1)

5. If (temperature is medium) and (humidity is low) then (fan is off) (cold light is on) (Warm Light is off) (1)

6. If (temperature is medium) and (humidity is average) then (fan is 50%) (cold light is on) (Warm Light is off) (1)

7. If (temperature is medium) and (humidity is high) then (fan is 100%) (cold light is on) (Warm Light is off) (1)

8. If (temperature is high) and (humidity is low) then (fan is 100%) (cold light is on) (Warm Light is off) (1)

9. If (temperature is high) and (humidity is average) then (fan is 100%) (cold light is on) (Warm Light is off) (1)

10. If (temperature is high) and (humidity is high) then (fan is 100%) (cold light is off) (Warm Light is off) (1)

Results

Preliminary tests were performed to evaluate seed germination. Figure 4 shows a series of 3 pictures where the evolution of seedlings taken every 24 hours can be seen.

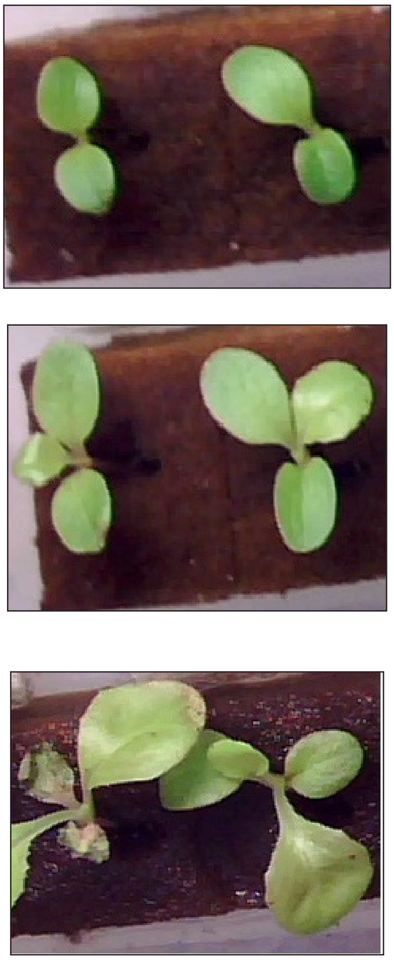


Figure 4: Sequence of photos taken with the webcam.

Performance evaluation of the chamber

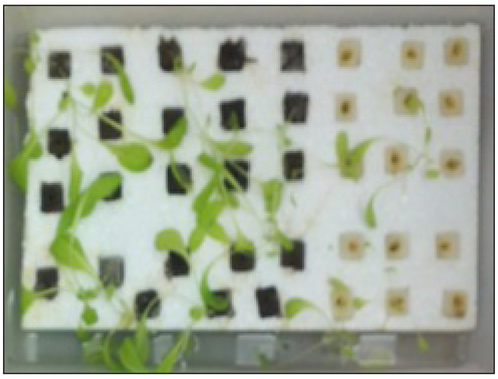
To evaluate the effectiveness of the germination chamber, a comparison was made between a conventional floating root in an adiabatic enclosure controlled by an air conditioner and a panel of fluorescent tubes that provide constant temperature by artificial lighting. Hydroponic nutrients were supplied in the same proportion in both containers. To check the amount of nutrients, EC (Electrical conductivity) was measured with a TDS (Total Dissolved Solid) digital conductivity meter, obtaining a value of 2000 ppm.

Measurements of light intensity with a Hetpa-instruments light meter with calibration certification were performed by INTI (Instituto Nacional de Tecnología Industrial). The measurements were carried out in the interior of the 2100 lux chamber.

PH measurements gave little variation, remaining at a level of 6.5, which is the range recommended in the literature.

In Figure 5, the difference in the quality of the seedlings can be appreciated.

A)



B)

Figure 5: Evolution of seedlings a) in tubs and b) in the germination chamber.

Data of germination temperature and relative humidity of each system can be seen in the graphs in Figures 6 and 7, where the stability of humidity and temperature in chamber can be appreciated.

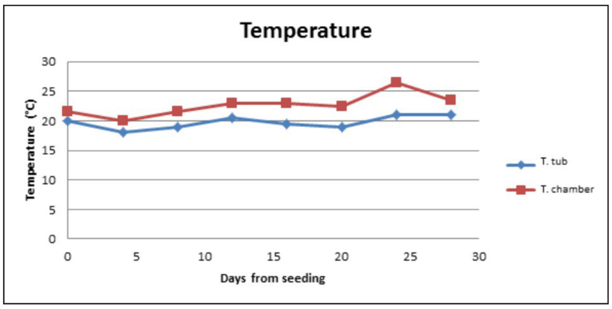


Figure 6: Relative temperature in chamber and tub.

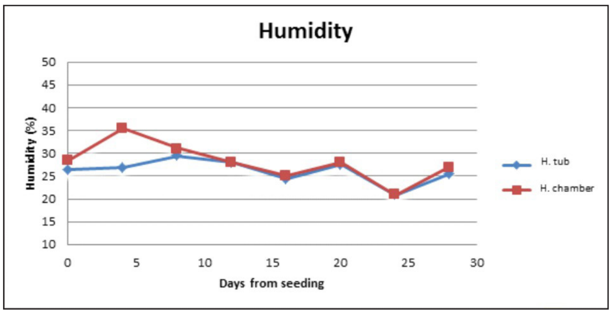


Figure 7: Relative humidity in chamber and tub.

In this study, from 20 samples studied, 2 did not germinate. The germinated samples had an average of 7.13 leaves, with a minimun of 6 and a maximum of 9 leaves per plant and an average length of 17.6 cm (Figure 8).

These values are higher than those reported in the literature by other authors in both commercial solutions as those obtained based on vinasse [8]. Moreover, Terry et al. [19] conducted experiences with application of different bioactive products in compacted ferrallitic red soil obtaining between 3.97 and 5.71 leaves per plant in soil at 30 days. These results are also lower than values obtained in this work.

Figure 8: Seedlings of 30 days old.

The chamber control is provided by the forced fan coupled with an arificial constant light microclimate with results in an increased production.

Considering the market costs necessary for the building of the equipment, the value of the manufactured equipment can be estimated according the figures presented in Table 1.

Table 1: Value of the manufactured equipment

Component Unit	Cost in dollars
Plastic Container	100
Control system	200
Pump	30
Sensors	30
Miscellaneous	50
Total	410

Control costs used in this work are lower than those used in other hydroponic systems as “Dynamic Root Floating Hydroponic” (DRF) [2] which utilizes digital control systems; the system is also difficult to implement for small producers. Other control systems using fuzzy logic in embedded systems such as Ponce et al. [20] do not show field results and others maintain nutrients stable and the amount of CO_2 [21] using costly sensors.

Conclusion

A pilot germination chamber with control based in fuzzy logic was designed and built to maintain environmental conditions involved in the development of seedlings from seed to transplant. The system reported data on a daily basis and maintained constant humidity, temperature, light intensity, EC and pH throughout the process. It was verified that the fuzzy control chamber has a performance superior to the conventional floating tray system in terms of leaves per plant.

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