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# IMPLEMENTATION OF DIRECT FUZZY CONTROLLER IN GREENHOUSE BASED ON LABVIEW

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**ABSTRACT:** *The techniques for climate control in greenhouse are to tune the crop needs and avoid unnecessary energy consumption. A greenhouse environment is an incredibly complex and dynamic environment. The use of Fuzzy Logic Controllers (FLCs) represents a powerful way to minimize and facilitate management of climate conditions of the modern greenhouse. Since the temperature of greenhouse was important factor that affects the crops growth and the yield, we have designed and investigated a computer based on direct fuzzy Controller for greenhouse temperature control system. In this study, we present the implementation of a fuzzy logic based control system for the regulation of climatic parameters under greenhouse using LabVIEW software through heating and cooling to ensure an exact range of temperature and humidity values. Some graphics user interfaces were developed, under LabVIEW software, for the real-time monitoring of the greenhouse system.*

**KEYWORDS:** Computer based control, direct fuzzy logic, Greenhouse climate, LabVIEW, Monitoring

## INTRODUCTION

The culture under greenhouse, in Morocco, is a sector in full development which requires great effort to achieve some performance levels in view of high cost and scarcity of fossil energies. The difficult current economic context obliges the producers to reduce their greenhouse production costs, to improve their performance and to seek the best sale price available by taking into account the context of market globalization. It was therefore necessary to develop technical production to produce all the year [1-4]. At first, the greenhouse was developed to protect the crops against extreme weather conditions, then for an early production by installing the control systems climate parameters, because the precocity was a pledge for better prices [5-7]. In addition, the producers must equip their greenhouses with modern climate control systems, in order to maximize efficiency and optimize quality. A greenhouse environment is an incredibly complex, a dynamic environment and it is difficult to predict all the interactions encountered in the greenhouse cultivation. Precise control of the greenhouse environment is critical in achieving the best and most efficient growing environment and efficiency. Fuzzy logic aims to study the imprecise knowledge representation and reasoning close to human language daily. Fuzzy logic provides a control law often effective, without having to resort to major theoretical developments. Indeed, fuzzy controllers have mainly demonstrated more robust performance compared to traditional techniques, in situations where the mathematical model of the process was not well known or when the behavior of the process varies non-linearly. It offers the advantage to include linguistic knowledge on how to control a nonlinear process like greenhouse, taking into account the experiences of growers. The use of Fuzzy Logic Controllers (FLCs) represents a powerful way to minimize and facilitate management of climate conditions of the modern greenhouses [8, 9]. Using fuzzy logic algorithms could enable machines to understand and respond to vague human concepts such as hot, cold, dry, etc [10, 11]. It also could provide a relativity simple approach to reach definite conclusions from imprecise information.

In this work we present a methodology for design, use of fuzzy logic based on direct fuzzy controller and its implementation for a real-time greenhouse temperature control system using LabVIEW software. We have developed an automatically control greenhouse climate system using fuzzy Logic to determine when to cool/heat and how much voltage we must apply to actuators (fan and heater). The primary aim of this study is to develop an automated climate control by the use of an intelligent robust system in order to regulate temperature under greenhouse, which integrates a PC-based monitoring system using a data acquisition card type PCI-6221 and a decision support system using fuzzy controllers with LabVIEW software [12, 13].

## GREENHOUSE SYSTEM

Figure 1 illustrates the different components of the electronic device developed for climate control under greenhouse. The experimental greenhouse used as support with these experiments is located in the Faculty of Sciences, Meknes, Morocco. It’s a greenhouse made of polyethylene single wall. The solution used a data acquisition card type PCI-6221 piloted by PC. The realized system allows measurement and saving of the different inputs/outputs values of physical magnitudes coming from different sensors (temperature, relative humidity, irradiance and $CO_2$ concentration). In order to regulate the temperature in a greenhouse, we have installed inside the greenhouse a heating system, pulsed air supply and a variable speed fan [18, 19]. A graphical user interface for supervision, which has been developed in LabVIEW, was used to monitor the greenhouse system.

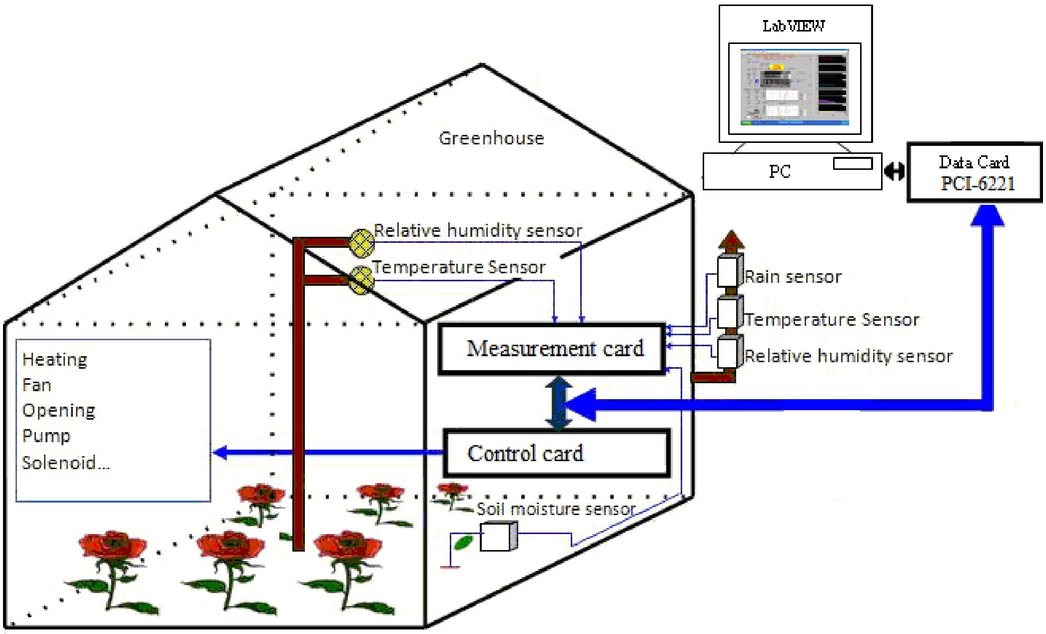
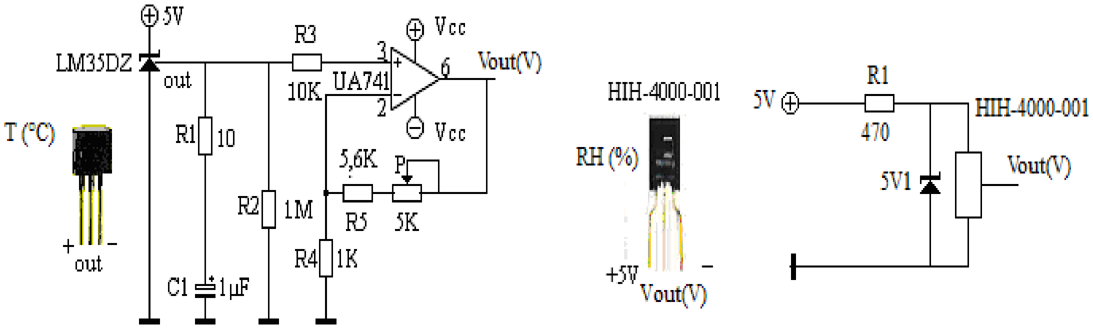


**Figure 1.** Experimental greenhouse set-up.

## 2.1 Measurement card



(a) Temperature sensor (b) Humidity sensor

**Figure 2.** Conditioning circuits for (a) temperature and (b) humidity measurments.

The temperature under greenhouse is measured using an LM35DZ temperature sensor. As seen in Figure 2(a), the output of the LM35DZ is filtered and amplified by a non-inverting amplificatory. The equation of variation of the output voltage of the circuit as a function of temperature is expressed by [18]:

$$T = 11{,}172 * V_{out} - 2{,}037 \tag{1}$$

With: T in °C and $V_{out}$ in Volt.

Figure 2(b) shows the humidity sensor HIH-4000-001 (Honeywell sensors) which is used to measure the relative humidity. This sensor delivers instrumentation-quality relative humidity sensing performance at a low cost. The measuring range of this sensor is from “5 to 95%”. Using the calibration curve of this sensor, the following formula is used:

$$RH = \frac{10^4}{62}\left(\frac{V_{out}}{V_{\text{supply}}} - 0{,}16\right) \tag{2}$$

Where: RH is expressed in %, $V_{out}$ in Volt and $V_{supply} = 5$ V.

## Control card

The static converter realized allows the actuator supply with alternating voltage. It is a single-phase dimmer, controlled by the phase, consists of two thyristors connected in anti-parallel as shown in Figure 3. The first thyristor Th1 is started during the positive half cycle with a delay angle $\alpha$. The second thyristor Th2 is started during the negative half cycle with a delay angle $\alpha + \pi$. It is possible, by controlling $U_c$ voltage to choose the time engaging a thyristor, the time of the extinction dependent on the characteristics of the receiver and may operate at the zero crossing of the current.

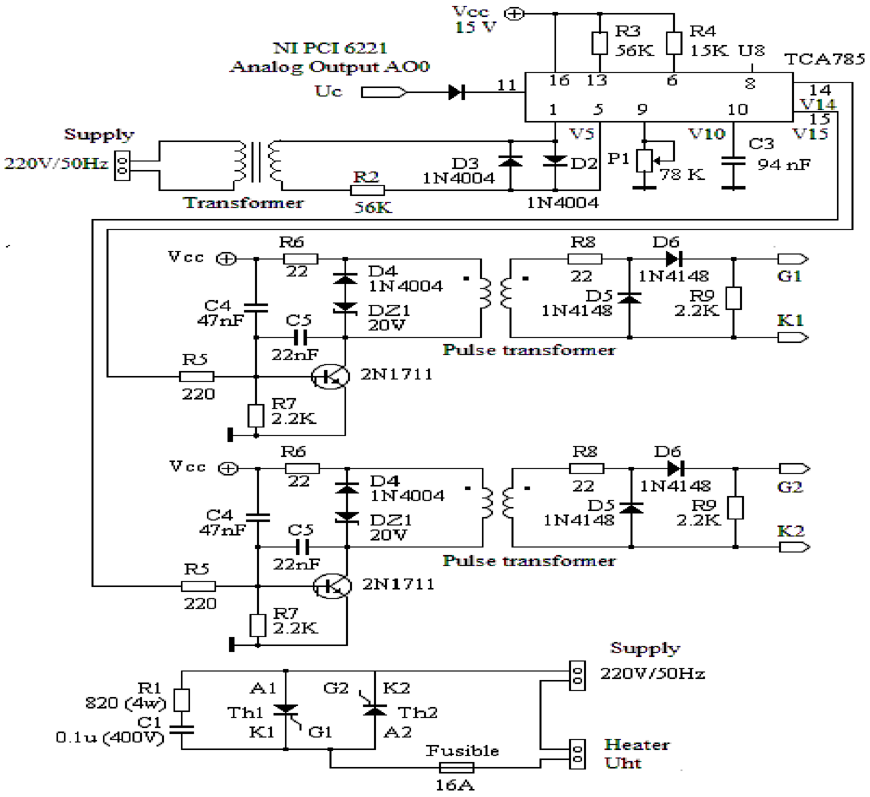


**Figure 3.** Control card.

The control circuit can generate pulses synchronized by the TCA785 for engagement of thyristors $Th_1$ and $Th_2$ at a galvanic isolation stage based pulse transformers. TCA 785 produces signals rectangular at the same period as the voltage $V_5$ and synchronization start time adjustable by the control voltage $U_c$. The angle of firing delay of the thyristor $Th_1$ is:

$$\alpha = 2.\pi.f.P_1.C_3\frac{U_c}{U_8} = K.U_c \tag{3}$$

With, $K = 2.\pi.f.P_1.C_3\frac{1}{U_8}$

The effective value of the voltage across the heater is:

$$U_{ht} = E\sqrt{1-\frac{\alpha}{\pi}+\frac{\sin(2\alpha)}{2\pi}} = E\sqrt{1-\frac{KU_c}{\pi}+\frac{\sin(2KU_c)}{2\pi}} \tag{4}$$

With, E = 220 V.
α: angle firing delay and $U_c$: Control voltage.
The power $P_{ht}$ supplied to the heating is expressed by:

$$P_{ht} = \left(\frac{U_{ht}}{E}\right)^2 P_{\max} = \left(1-\frac{KU_c}{\pi}+\frac{\sin(2KU_c)}{2\pi}\right).P_{\max} \tag{5}$$

With, $P_{max}$ = 400 W.
The figure 4 shows the variations of voltage and power supplied to the heating depending on the driving voltage $U_c$.

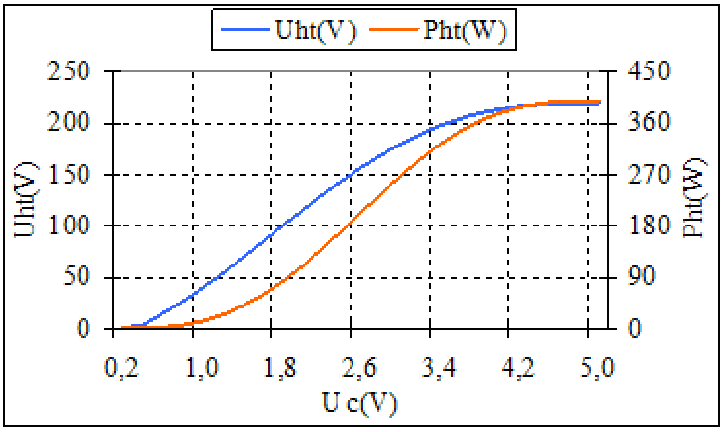


**Figure 4.** Evolution of $U_{ht}$ and $P_{ht}$ depending $U_c$ .

## FUZZY GREENHOUSE CONTROLLER

The Mamdani fuzzy inference mechanism is useful when applying Fuzzy Logic to the control of systems. If we consider a classic feedback scheme, the Mamdani fuzzy inference mechanism is useful when applying Fuzzy Logic to the control of systems. The idea, put forth by Zadeh, for using Fuzzy Control algorithms relies on introducing the knowledge base into the controller such that its output is determined by the control rules proposed by the expert. A frame diagram for a fuzzy control greenhouse system is shown in figure 5. Two input linguistic variables of fuzzy controller are given as, $\Delta T = T_s - T_{in}$ ($T_s$: set-point temperature, $T_{in}$: inside temperature), and $\Delta RH = RH_s - RH_{in}$ ($RH_s$: set-point humidity, $RH_{in}$: inside relative humidity).

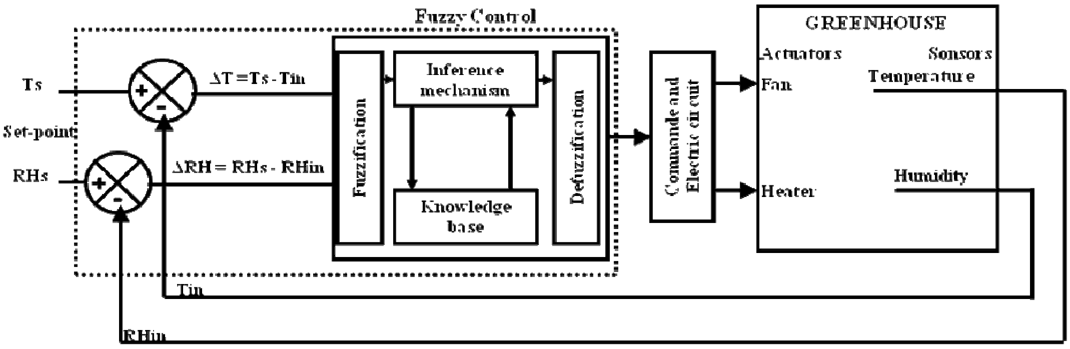


**Figure 5.** The temperature and humidity frame diagram fuzzy control.

The main complexity of implementing a fuzzy logic controller involves incorporation of the discrete nature of the staged heating/ventilating equipment. It is not necessary to use a mathematic model in the process of the temperature control using fuzzy logic controller, but must know only the relations between input and output variables of the greenhouse [20-22]. In this part, PC-based LabVIEW was used to implement a fuzzy logic-based temperature control greenhouse. The system is aimed at controlling the temperature of an environment by regulating a heater and the speed of a fan. The fuzzy controller has to make decisions based on difference between set-point and measured inputs variable.

The variable “temperature” which is inputted on the system can be divided into a range of three states such as “Cold”, “Normal” and “Warm”. Defining the bounds of these states is a bit tricky [8,23-25,]. An arbitrary threshold might be used to separate “Cool” from “Warm”, but this would result in a discontinuous change when the input value passes over that threshold. The way to make the states “fuzzy” is to allow them change gradually from one state to the next Membership function is always gotten by experience, so it has greater randomness. The choice of the fuzzy variable Membership function has certain influence on the functions of the fuzzy controller. The fuzzy controller parameters in these experiments are summarized in Table 1.

**Table 1.** Range and the number of membership function of fuzzy controller parameters

| Name | Range | Number of membership functions | Membership function | Shape | Points |
|---|---|---|---|---|---|
| Temperature<br>($\Delta T = T_s - T_{in}$) | -20 to 20 | 3 | Warm | Trapezoid | -20 ; -20 ; -10 ; -2,5 |
| | | | Normal | Sigmoid | -10 ; -5 ; 5 ; 10 |
| | | | Cold | Trapezoid | 2,5 ; 10 ; 20 ; 20 |
| | | | Wet | Gaussian | -20 ; -15 ; -10 ; |

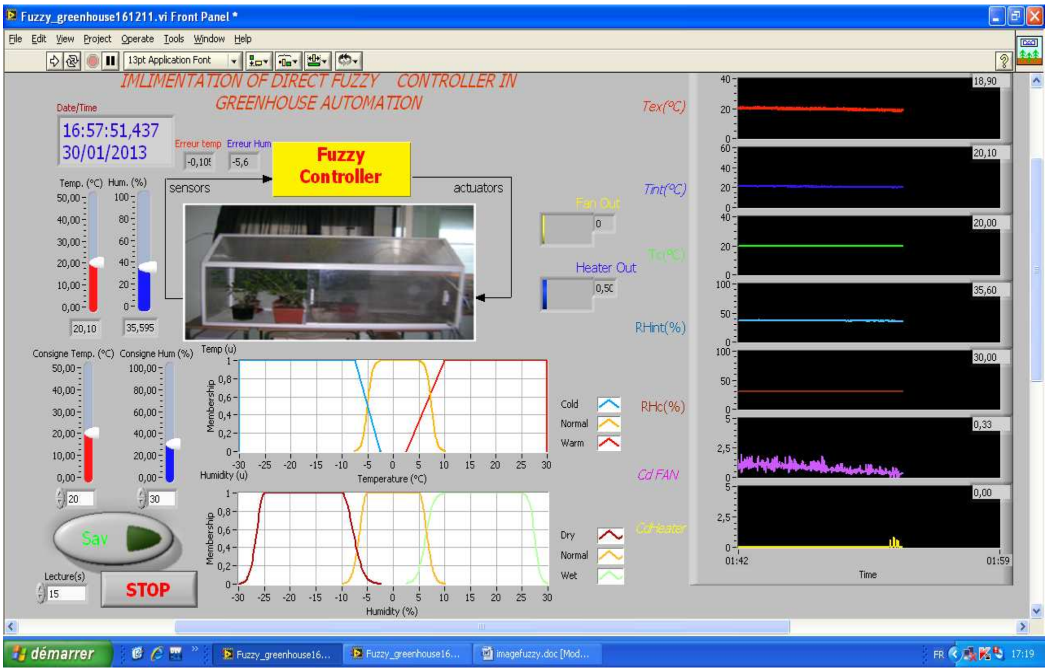
| | | | | | |
|---|---|---|---|---|---|
| Humidity<br>$(\Delta RH=RH_s-RH_{in})$ | -20 to 20 | 3 | Normal<br>Dry | Gaussian<br>Gaussian | -2,5<br>-10 ;-2,5 ; 2,5 ; 10<br>2,5 ; 10 ; 15 ; 20 |
| Command Fan ($Cd_F$) | 0 to 5 | 3 | OFF<br>LOW<br>HIGH | Triangle<br>Triangle<br>Triangle | 0 ; 0 ; 2,5<br>0 ; 2,5 ; 5<br>2.5 ; 5 ; 5 |
| Command Heater ($Cd_H$) | 0 to 5 | 3 | OFF<br>LOW<br>HIGH | Triangle<br>Triangle<br>Triangle | 0 ; 0 ; 2,5<br>0 ; 2,5 ; 5<br>2.5 ; 5 ; 5 |

We choose the triangle form of Membership function of Ventilation and heater controlled output for the purpose to achieve simplified calculation. 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 inference engine to the output of the model to a standard crisp signal. The centroid method of defuzzification takes a weighted sum of the designated consequences of the rules according to the firing strengths of the rules. Fuzzy rules are a collection of linguistic statements that describe how the fuzzy controller should make a decision regarding classifying an input or controlling an output. Fuzzy rules are always written in the following form:

1. IF 'Temperature' IS 'Warm' AND 'Humidity' IS 'Wet' THEN 'Command FAN' IS 'OFF' ALSO 'Command Heater' IS 'LOW'.
2. IF 'Temperature' IS 'Warm' AND 'Humidity' IS 'Normal' THEN 'Command FAN' IS 'LOW' ALSO 'Command Heater' IS 'OFF'.
3. IF 'Temperature' IS 'Warm' AND 'Humidity' IS 'Dry' THEN 'Command FAN' IS 'HIGH' ALSO 'Command Heater' IS 'OFF'.
4. IF 'Temperature' IS 'Normal' AND 'Humidity' IS 'Wet' THEN 'Command FAN' IS 'LOW' ALSO 'Command Heater' IS 'HIGH'.
5. IF 'Temperature' IS 'Normal' AND 'Humidity' IS 'Normal' THEN 'Command FAN' IS 'OFF' ALSO 'Command Heater' IS 'OFF'.
6. IF 'Temperature' IS 'Normal' AND 'Humidity' IS 'Dry' THEN 'Command FAN' IS 'LOW' ALSO 'Command Heater' IS 'OFF'.
7. IF 'Temperature' IS 'Cold' AND 'Humidity' IS 'Wet' THEN 'Command FAN' IS 'OFF' ALSO 'Command Heater' IS 'HIGH'.
8. IF 'Temperature' IS 'Cold' AND 'Humidity' IS 'Normal' THEN 'Command FAN' IS 'OFF' ALSO 'Command Heater' IS 'LOW'.
9. IF 'Temperature' IS 'Cold' AND 'Humidity' IS 'Dry' THEN 'Command FAN' IS 'HIGH' ALSO 'Command Heater' IS 'LOW'.

## DEVELOPED INTERFACE FUZZY CONTROL AND MONITORING

A software for computer based fuzzy logic for greenhouse temperature control has been developed using LabVIEW. The software is based on the graphic user interface (GUI). It displays a text box, which enables the user to monitor current value of the parameter (temperature and humidity) being measured and controlled, and the fuzzy controller parameters. It also features to enter the new set point; filename to store measured data…etc. The dashboard of climate fuzzy control and monitoring is shown in figure 6. The driving software enables us to fix thresholds of temperature and humidity.



Date/Time 16:57:51,437 30/01/2013
Erreur temp -0,10
Erreur Hum -5,6
Temp. (°C) 20,10
Hum. (%) 35,595
Fan Out 0
Heater Out 0,50
Consigne Temp. (°C) 20
Consigne Hum (%) 30
Lecture(s) 15
Tex(°C) 18,90
Tint(°C) 20,10
Tc(°C) 20,00
RHint(%) 35,60
RHc(%) 30,00
Cd FAN 0,33
CdHeater 0,00

**Figure 6.** The dashboard of climate fuzzy control and monitoring

The work on the application of fuzzy techniques for crop production has been done by several investigators Sriram et al. [11], Gouda [20] and Nachidi et al. [21]. However, the combination of fuzzy controller and LabVIEW software has not been explored thoroughly to support the process control in greenhouses. This work discusses the design and practical implementation of a computer-based control system that integrates fuzzy control techniques. The system was designed to accurately regulate in real-times two environmental parameters (i.e. humidity, temperature) inside a greenhouse in an integrated fashion.

## RESULTS AND DISCUSSION

We will present the main results of experimental measurements of climatic parameters (temperature, relative humidity of the air ...) performed in the experimental greenhouse. The aim is to maintain the air temperature in the range of 20°C and the relative humidity air in the range of 50%. The choice of the temperature and humidity range depends on the climatic requirements of the plants. The climatic parameters are measured and stored every minute. Figure 7 shows the results for the uncontrolled experiment performed between 3rd – 6th, December 2012. The data were recorded with no operation of fan and heater. These curves show a comparison between the inside ($T_{in}$) and the outside temperature ($T_{out}$). The results show that the external temperature curve follows the same variation as of the internal temperature. Furthermore, the internal temperature values, appeared during the day and night, remain too high due to the greenhouse effect. The measurements obtained have allowed us to have a database of information on inputs, outputs and process disturbances [26, 27].

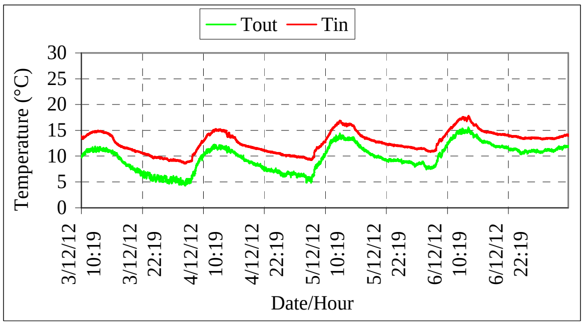


**Figure 7.** Measured internal and external temperatures with no-control operation

Figure 8 shows the fuzzy controller test. Tests were conducted to see whether the fuzzy controller system gives the correct voltage to the power board that supplies the actuators depending on difference between the set-point ($T_s$) and measured values (figure 8.a) . We note that the fan command voltage Cd-Fan is high when $\Delta T = T_s - T_{in}$ is low and $\Delta RH = RH_s - RH_{in}$ is high. The heater command voltage Cd-Heater is high when $\Delta T = T_s - T_{in}$ high and $\Delta RH = RH_s - RH_{in}$ is low (figure 8.b). It can be seen that, the heating system engages when the inside temperature becomes lower than the set-point temperature. On the other hand, the fan system functions. Indeed, when the temperature increases the relative humidity decreases and vice versa.

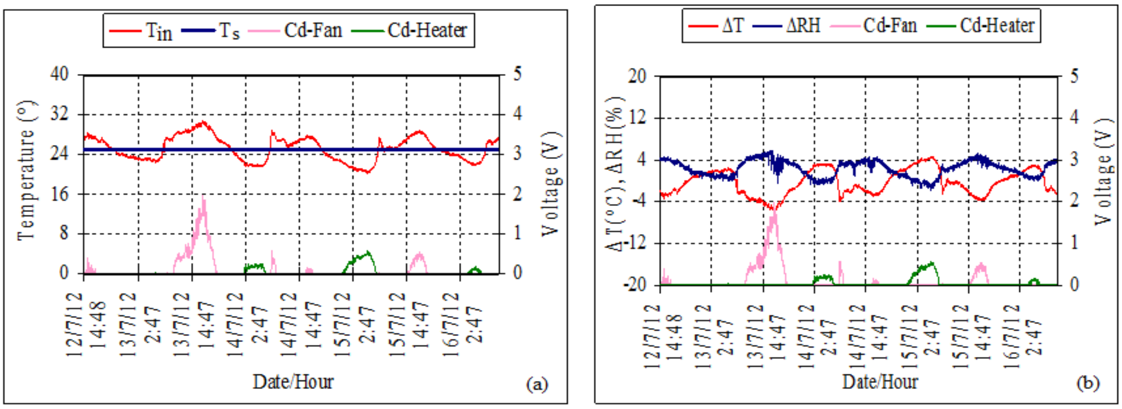


**Figure 8.** Fuzzy controller test

From the results shown in Figure 9 and Figure 10 it can be concluded that the overall performance of the fuzzy controller to maintain the temperature and the humidity within a given range, around the set points, is satisfactory. The outside temperature is in the interval [8 °C, 18 °C]. We note that the temperature in the greenhouse is maintained in the desired range 20 °C in the night and in the day. It can be shown that the relative humidity under greenhouse is influenced by the inside temperature and varies in the interval of [47 %, 55 %].

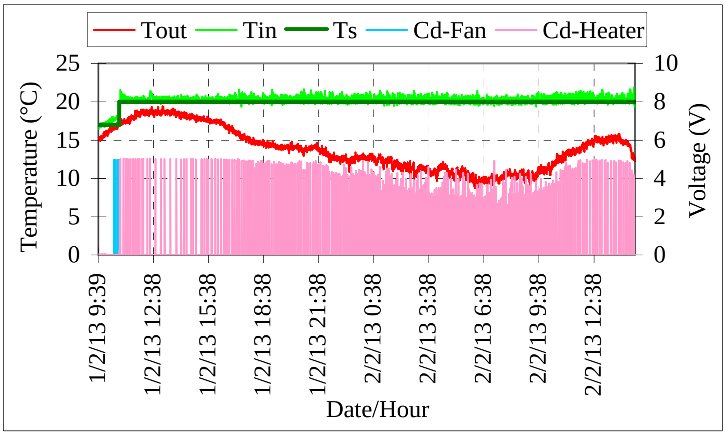


**Figure 9.** Measured temperatures and Heating/ventilation level for the direct fuzzy control strategy.

We observed that the inside temperature follows correctly the set-point independently of changes in outside temperature which decreases from 8°C to 18°C. Compared to our previous investigations [8] and the existing ones [20], we have found that our system overcame successfully the known shortcomings in terms of power consumption and its facile implementation in greenhouse based on LabVIEW software. Indeed, we have developed an automatically control greenhouse climate system using fuzzy Logic under LabVIEW software to determine when to cool/heat and how much voltage we must apply to actuators (fan and heater). Hence, the developed electronic power card based on dimmer allowed to modulate the electric power supplied to the actuators.

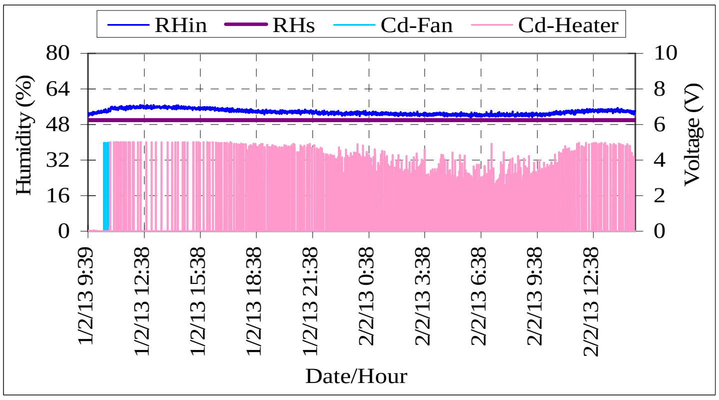


**Figure 10.** Measured relative humidity under the action fuzzy.

## CONCLUSION

A greenhouse temperature and humidity control algorithm based on direct Fuzzy logic controller were designed, tested and implemented. Several actuators and sensors are installed and connected to an acquisition and control system based on personal computer and a data acquisition card. The overall tests indicated that the fuzzy controller worked satisfactory but at the expense of actuators frequent activity. This research has successfully showed that LabVIEW and Fuzzy Logic controller can be applied to develop a system for monitoring climate parameters under greenhouse. Using a computer system can cause some difficulties for the producer inexperienced with computers. But the developed system has advantages that the designed program is user-friendly and the results could be easy to analyze by the user, as the front panel is a graphical user interface. The use of fuzzy logic requires however, the knowledge of a human expert to create an algorithm that mimics his/her expertise and thinking.

## Acknowledgments

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