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Modeling and comparison of fuzzy and on/off controller in a mushroom growing hall

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A B S T R A C T

Mushroom production is one of the biggest solid state fermentation industries in the world. The success in mushroom planting depends on how the control temperature, humidity and CO_2 parameters. This paper presents a novel method for modeling an environment of mushrooms growth to comparing the performance of two controlling methods (fuzzy logic and digital (ON/OFF) control) for controlling mentioned parameters on production rate. The Controllers and other equipment were developed to data collection and analysis of these parameters was performed by using Simulink part of MATLAB software. Precise control of the parameters involved in the growth of mushrooms caused to improve product quality and reduced energy consumption. The results of tests and mean value obtained on two different methods showed that the fuzzy controlling with having least standard deviation, variance and error, is better than digital controlling. Fuzzy controlling system had the lowest fluctuation and lowest band pass. According to gradient of graph, maximum and minimum of results, can conclude that the fuzzy controlling has shown better response in controlling the process. Based on the number of actuators mode changing on both systems, it can be understood that in digital control system, downtime, and depreciation and energy consumption would be higher than the fuzzy control system.

1. Introduction

By population growth, Agricultural products play an important role to Provide food. Agricultural products have always been the main supplier of human nutritional requirements. Greenhouse production is one of the modern methods on agricultural productions. Mushroom production is too close and similar to greenhouse production. The Successful mushroom growing depend on overcome difficulties arising from variation of temperature, humidity and CO_2 concentration [1]. The greenhouse environment control problem is to create a favorable environment for the crop in order to reach predetermined results for high yield, high quality and low costs. It is a very difficult control problem to implement in practice due to the complexity of the greenhouse environments. For example, they are highly nonlinear, strong coupled and Multi-Input Multi-Output (MIMO) systems, they present dynamic behaviors and they are largely perturbed by the outside weather (wind velocity, outside temperature and humidity, etc.) and also by many other practical constraints (actuators, moistening cycle, etc.) [2].

In the past few decades, the stability analysis and control design problem of switched systems have achieved great progress [3–7]. By development of computer systems and electronic equipment the need to test and evaluate advance controllers to achieve the best affordable climate control systems, increases [8]. Mushroom production involves several stages. Each of these stages require different temperature, humidity and carbon dioxide. Investigation of the implicated parameters in mushroom production halls can be one of the main factors to reduce energy consumption and to increase the quantity and quality of the product. The implicated parameters of environment control of mushroom production halls can be influenced by factors such as weather conditions, operator mistake and uncontrolled entrance into the mushroom production halls in order to control parameters. The lack of appropriate control system makes uncontrolled operator entry to control the parameters. This action in addition to stir the atmosphere balance of growing hall, can cause contamination the inside atmosphere of the growing hall [1]. Researchers have used many control techniques in different fields. From the classic control theory such as: proportional, integral and derivative (PID) controllers, artificial intelligence (AI) such as fuzzy logic systems (FLS), artificial neural networks (ANNs) and genetic algorithms (GAs) to advanced

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Nomenclature

A	heat transfer area (m^2)
C_p	specific heat (kj/kg k)
D	diameter (m)
h	heat transfer coefficient ($w/c^0\ m^2$)
k	thermal conductivity (w/m k)
L	length (m)
M	mass (kg)
m	mass flow (kg/s)
Nu	Nusselt number
Pr	Prandtl number
q	heat transfer (w)
Re	Reynolds number
RH	relative humidity (%)
Sprayer	rate of water spraying (m^3/s)
T	temperature (°C)
U	overall heat transfer coefficient ($Kw/m^2\ c^0$)
V	volume of area (m^3)
v	ventilation rate (m^3/s)

Subscripts

a	air
amb	ambient
ex	external
in	internal, indoor
max	maximum
out	outdoor
r	roof
Sa	supply air
W_1	east and west walls
W_2	south and north walls

techniques like predictive, adaptive, robust and non-linear control [9]. Generally, control systems with on/off switching have been satisfactory for greenhouse climate management for some growers. The advantages of this system are its easiness to use and its affordability; however, for research and commercial purposes, more precise control is needed [10,11]. On the other hand, fuzzy logic is simple to use if incorporated with analog-to-digital converters, and 4-bit or 8-bit one-chip micro controllers. This can easily be upgraded by changing rules to improve performance or add new features to the system. In many cases, fuzzy control can be used to improve existing controller systems by adding an extra layer of intelligence to the current control method [8]. fuzzy modeling has some distinctive advantages, such as the mechanism of reasoning in human understandable terms, the capacity of taking linguistic information from human experts and combining it with numerical data and the ability of approximating complex nonlinear functions with simple models [12].

However, to the authors' best knowledge; very few publications are available in the literatures that discuss the issue of Modeling and Comparison of fuzzy and on/off controller in a model mushroom growing hall. The purpose of this study is to design fuzzy and ON/Off controllers in order to control indoor temperature, relative humidity and carbon dioxide of growing hall. These objectives can be achieved by developing, a good prediction model of the inside air temperature and humidity, as the first stage and in the second stage, a control law to permit to these outputs to follow specific values depending on the plants nature. The next step is to compare two controllers performance. This paper has been modeled based on theoretical and experimental research on a mushroom production company in Ardabil province of Iran. The cold weather of region affected on controlling algorithm. These objectives can be achieved by developing, a good prediction model of the inside air temperature and humidity, as the first stage and in the second stage, a control law to permit to these outputs to follow specific values depending on the plants nature. In this paper, we are interested only in the modeling phase. Reminder of the paper is organized as into 4 sections:

Section 2 analyses actuators model, zone model, fuzzy model, Digital controller and Simulink. Experimental results are presented in Section 3. Section 4 concludes the paper.

2. Material and methods

In the past few decades, the stability analysis and control design problem of switched systems have achieved great progress [3–7]. One of the most important steps to designing a control system is modeling. A good model permits from the one hand to test a controller before its implementation in the real process and from the other hand to make possibility to use it. Typical applications of these models are the simulation, the prediction or the control system design [13,12].

2.1. Actuators model

In this study, we try to find modeling a good control system to control of actuators. This system is able to supply requirement heating, cooling and relative humidity and controlling the concentration of carbon dioxide by using damper. The most important actuator install on air handler.

The HVAC[1] Model system is consisted of 3 parts. The first part is heating/cooling coils to heat transferring, the second part is water pump to supply required relative humidity on productions and air damper for air circulation is third part. We provide modeling of each part, separately and combined them by unique method. For determine heat transfer modeling has been used an internal and external heat transfer equations (Eqs. (1)–(7))[14]:

$$Nu_{in} = 3.66 + \frac{0.0668(D/L)Re_d Pr}{1 + 0.04[(D/L)Re_d Pr]^{2/3}} \tag{1}$$

$$h_{in/ex} = \frac{Nu_{in/ex}k}{D} \tag{2}$$

$$Nu_{ex} = C^m C_2 Re_{d,max} P^{0.36}(Pr/Pr_s)^{1/4} \tag{3}$$

$$U = \frac{1}{(1/h_{in}) + (1h_{ex})} \tag{4}$$

$$NTU = UA/C_{min} \tag{5}$$

$$\in = \frac{(T_{h,i} - T_{h,o})}{(T_{h,i} - T_{c,i})} = \frac{(1 - exp\{-NTY[1 + (C_{min}/C_{min})]\})}{(1 + (C_{min}/C_{max}))} \tag{6}$$

$$q = \in q_{max} \tag{7}$$

Eqs. (1) and (3) help us to find Nusselt number for internal (Nu_{in}) and external (Nu_{ex}) flow, respectively. Eq. (2) gives us convection coefficient that is found using Nusselt number. Using the Eq. (4) give overall heat transfer coefficient. After this steps, using Eqs. (5)–(7) give us the overall heat transfer.

[1] HVAC: Heating, Ventilating and Air Conditioning.