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Recovery of irrigation water for greenhouses

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Abstract

Plants need a favorable environment in which they are able not only to live but also to produce. One of the biggest concerns that any producer lives is the shortage of water, agricultural use of reclaimed water is an option that is being studied and adopting increasingly water-scarce regions, growing urban populations and increased demand for irrigation water.In the present work is to provide a tool to address this serious problem, have developed many projects for collecting rainwater, have generated solutions in the reuse of domestic wastewater, all they applied to irrigation of vegetables or greenhouses. They have developed hydroponic and aeroponic systems are designed efficient irrigation systems, but they all precious resource losses are generated. In this design you want to recover the irrigation water that is done, because usually you lose, there has been regarded as an important value in terms of volume.

Water Recovery, Mathematical Modeling, Numerical Methods

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1. Introduction

Many regions of the world are experiencing increasing problems of water shortages. This is due to the relentless growth in demand for water in front of a static or declining water resources and periodic droughts due to climate factors (Winnpeny, Heinz, & Koo-Oshima, 2013).

In times of extreme scarcity, national authorities often choose to divert water from farmers to the cities, because the water has a higher economic value in its industrial and urban use in most agricultural purposes (Winnpeny, Heinz, & Koo-Oshima, 2013). This situation leads to design strategies to recover water from domestic activities, rain, waste, in many places have opened investigations where water is recovered by condensation in dwellings or greenhouse.

The countries most concerned about this situation is the European Community, which have generated a number of investigations in this regard (European Commission, 2015), these works have sparked a significant amount of development, whose main objective is to recover water, today more water is required to recover all the activities we develop.

This situation leads to the need to use auxiliary methods, which help ensure that the developed system will meet the requirements of design, one of those tools is the mathematical modeling.

On a scientific level, to describe reality and make predictions for the future models, which can be performed as scale representations (such as models) to mathematical models that explain natural phenomena develop. In agriculture, these can be used to define how much water and fertilizer to apply, as well as to predict the incidence or progression of a pest or disease (Hernandez, 2015).

Montgomery (1991) suggests that mathematical models are more concise and less ambiguous; This, together with the availability of rules that can be used mechanically, can describe more complex situations, with less effort, and less risk of confusion. Regression methods are often used to analyze data coming from experiments that were not designed or where you can not have control over variability.

This situation leads to suggest that the recovery of irrigation water plants, can be predicted using mathematical models, using a good model will allow to design the most appropriate control system, using the necessary variables. The more variables studied in a mathematical model can generate more accurate representation of reality, for scientific research shows that increasing the number of variables studied produce more accurate model (Hernandez, 2015).

Once data are now another problem arises, how to analyze the data in ways that are consistent, systematic and foremost, to answer the hypotheses. Today the world has increased the need for research in statistical models and advanced mathematical tools (Rodriguez, 2001). The use and proper interpretation of these techniques pemiten making optimal decisions, efficiency and achieving greater efforts in different areas and in spiced up the agricultural sector, whose application encourages the development of productive systems (Rodriguez & Bermúdez, 1995).

An example of this is the transfer of novel statistical analysis techniques that are applied in other branches of science, based on the physical and chemical properties of the materials to the field of agricultural engineering (Betancourt, Rodriguez, & Pineda, 2009) properties.

Applied Mathematics in agricultural sciences allow criteria and provide basic tools for interpreting man handle better and better farming, meet the demands of new technologies to produce in highly competitive global markets while protecting natural resources and make decisions in the medium and long term conditions Similar experimentation (Ortega, 2000).

Based on these approaches there is a need to understand the nature of the process, closely related to the research and know some of the tools most used chords Applied Mathematics the target of the investigation. Situation resulting experimentation to make this project, where once irrigation data collected will be submitted to a mathematical treatment that allows to know the mathematical function of the system behavior and determine the efficiency of the project.

2. Theoretical framework

2.1. Water recovery

Fresh water is approximately 0.6% of the total amount of water on the planet. The freshwater resource is unevenly distributed and water quality is deteriorating in many parts of the world, but also an improvement in some places. In the world water crisis is present. The cause of this crisis may be attributed to the lack of precipitation and limited resource, in addition to increased demand for the sectors: agricultural, urban and industrial, also most of the water available globally it is used to irrigate crops (He raised 1998).

Lost water is to capture the resource, water various activities currently recovers: domestic, which are known as wastewater, rain or condensation, more recent research, the scarcity of water in all its aspects has serious costs economic, social and even political.

Reuse of wastewater in agriculture is an element of development of water resources and innovative leadership that maintains an alternative for agriculture. The reuse of reclaimed water for irrigation enhances agricultural productivity; this provides water and nutrients, and improves crop yields. However, it requires protection of public health, appropriate treatment technology, reliability treatment, water use, acceptance and participation must also be economically and financially viable (Bahri, 1999).

2.2. Mathematical model

The scientific activity is inconceivable without the development of mathematical models to synthesize and increase existing knowledge about a system. Agricultural research and especially the science and art of horticulture are no exception. Mathematical models allow you to test scientific hypotheses vegetables and also have potential application in both education and practice of horticulture. The models used to evaluate possible strategies of managing a greenhouse without carrying out costly experiments (Lopez-Cruz Ramirez-Arias & Rojano-Aguilar, 2005).

The comprehensive nature of the solution of current scientific and economic tasks, as well as the high efficiency of the specialized methods used to influence work objectives demand a high preparation specialist, in particular the agricultural industry, to enable it issue opinions in agricultural processes, with high levels of reliability (Chavez, Sabin, Toledo, & Jimenez, 2013).

Over the past 15 years we have developed mathematical models for vegetables grown under greenhouse conditions. Gary et al. (1998a) reported that the number of species studied to this year amounted to 25 fruit species, 23 plant species grown in the open, 20 and 4 ornamental plants grown in the greenhouse.

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2.3.Numerical methods

Applied mathematics consists of a set of useful tools for various purposes, ranging from the Statistics, process optimization, numerical mathematics and the use of finite elements (Alvarez & Urrutia, 2000).

An example of these applications is the non-linear regression, for describing physical and biological systems (Rebolledo, 1994). Ostle (1986) and Montgomery (1991) proposed that if the linear model is not appropriate, consider setting a nonlinear model. For Rodriguez (1989) and Graybill and Iyer (1994), models seem to be non-linear can become using any suitable linear transformation of the response variable, the predictor variables, parameters, or combination thereof. Some nonlinear models include logistic, exponential, Michaelis-Menten and monomolecular.

3. Basic principles and energy technologies

In this paper a prototype to simulate the behavior of the system, which is presented in Figure 1, Figures 2 and 3 the schematic wiring diagrams and sensor with Arduino UNO presented is generated.

This type of sensor operating characteristics and low cost in the market, this sensor has the same performance as a radar sends pulses at high frequency ultrasound in this case was selected. It can be expressed mathematically as: $d = 170(^{m}/_{s}) \times t$.

Figure 1 Model of the irrigation system, the Ultrasonic sensor shown

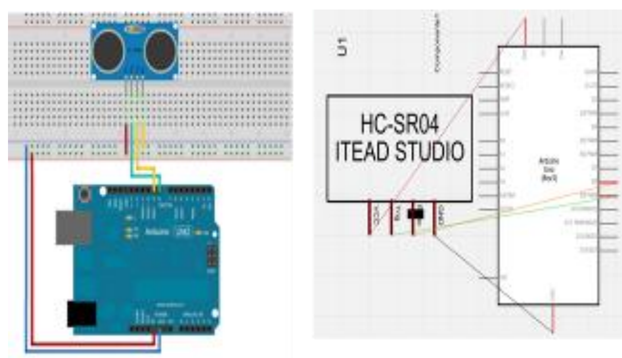

Figure 2 Protoboard connection and connection scheme

The Arduino board one is used as a simple, cheap and effective data acquisition card, coupled with its ease of programming, then the Arduino code developed for obtaining data shown:

```
/*
        Rosa María de Anda López
        Sensor ultrasónico HC-SR04 para control
        de tamaño de riego
        Ahorro de energía
        */
        #define echoPin 8
        #define triggerPin 9
        #define ledPin 13
        int delaymili = 500;
        int maximumRangeCm = 200;
```

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```
int minimumRangeCm = 0;
long duration, distanceCm;
void setup() {
        Serial.begin(9600);
        pinMode(triggerPin, OUTPUT);
        pinMode(echoPin, INPUT);
        pinMode(ledPin, OUTPUT);
}
void loop() {
        initTrigger();
        duration = pulseIn(echoPin, HIGH);
        distanceCm = microsecCm(duration);
        if (distanceCm >= maximumRangeCm || distanceCm <= minimumRangeCm) {
                Serial.println("Out of range");
                digitalWrite(ledPin, HIGH);
        }
        else {
                digitalWrite(ledPin, LOW);
                Serial.print("Distance in cm: ");

        Serial.println(distanceCm);
                delay(delaymili);
        }
}
long microsecCm(long microsecond) {
        return microsecond / 58;
}
void initTrigger() {
        digitalWrite(triggerPin, LOW);
        delayMicroseconds(2);
        digitalWrite(triggerPin, HIGH);
        delayMicroseconds(10);
        digitalWrite(triggerPin, LOW);
}
```

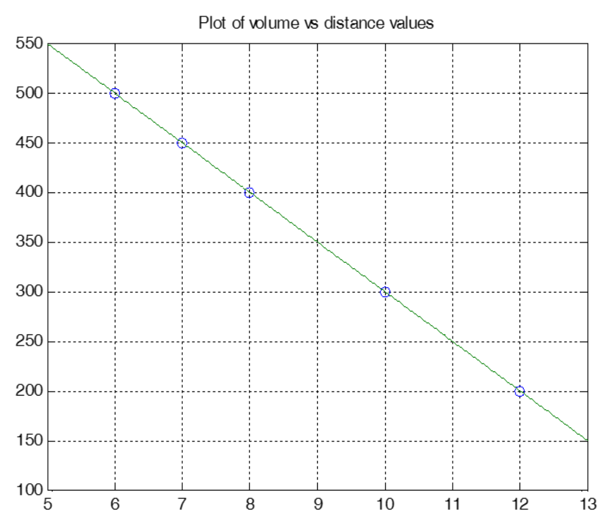
4. Economic Sustainability

The results obtained in making data were analyzed and processed by first obtaining the mathematical model of the process.

Firstly vectors determined values of the sensor and the volume meter are obtained the vectors: d = [6 7 8 10 12] v = [500 450 400 300 200], where the first value is the detected distance, in cm and the second volume is given in ml. With these values the corresponding graph in matlab, is built for observer behavior characteristic polynomial function, with the following results:

```
clc
clear all
close all
t=[6 7 8 10 12];
v=[500 450 400 300 200];
x=5:0.01:13;
y=interp1(t,v,x,'spline');
plot(t,v,'o',x,y)
grid on
title('Gráfica de valores distancia  vs  volumen')
```

Where the graph of Graph 1 shows that the behavior is linear.



Graph 1 Graphic System Behavior

Taking two points thrown sensor: $x1 = (6, 500)$ $x2 = (10, 300)$, the function is built:

$$y - 500 = (x - 6)\left(\frac{300-500}{10-6}\right) \quad (1)$$

Simplifying the equation 1 is obtained:

$$y = -50x + 800 \quad (2)$$

What it represents us the function modeling system.

And with these data, an application in matlab, where a linear interpolation is performed to determine the volume at any position (distance) is generated.

```
clc
clear all
close all
syms x
x=input(' The distance value is:  ');
y=-50*x+800
```

Now have to perform measurement system efficiency, irrigation of 200 ml is performed with a time of 26 seconds, after 3 hours of runoff water volume recovered is measured, resulting in a recovery of 75 ml, it giving the system an efficiency of 37.5%, if it takes a real size of 10 000 plants in a greenhouse, and each plant was subjected to the same treatment, presumably could be obtained 750 000 ml of water recovered in total system, this represents a reservoir 750 liters, which would represent 200 ml irrigation 3750, with recovery logic 75 ml. these data are again reaffirms 37.5% efficiency.

Representing sustainability of the greenhouse, knowing that water is one of the most coveted resources in certain regions, where their scarcity, it becomes vital resource for production.

5. Diagnosis of energy consumption

Research has been conducted wherein the means for collecting water is provided through which rain water is used other residuals and other major projects have been started in designs where condensation is one of the means for withdrawal of water.

Mainly countries such as Chile, Colombia and Spain are countries that have been working hard on these issues, since water has become a very precious resource, Valparaiso University is working with an intelligent greenhouse, where the new technology that the greenhouse will allow you to reuse 70% of water and control evapotranspired climatic parameters (temperature and humidity) and irrigation remotely through software.

In Spain, specifically in the region of Almeria, systems that capture 75% of rainwater to be used to irrigate crops in greenhouses are generated, also are designing treatment plants that allow use wastewater as it should avoid heavy residues, metals, bacteria, viruses and those microorganisms that might contaminate the culture, these systems are having an efficiency of 70%, it requires only elements that raise the irrigation.

The proposed system has the advantage that recovery of water is created by gravity, directing it to the tank allocated, only the elements present on the crop, which makes the water can be reused without danger of contamination, and same switching on the pump automate, so that will turn 3 times per day, representing a saving in energy costs of 70%. Both situations combined greenhouse ensures sustainability. Annex 1 an analysis of energy savings and payback shown

6. Comprehensive program of energy saving

This project presents benefits allowing it to be sustainable, given that the water recovery system for irrigation, which will be entirely by gravity, which will greatly reduce the use of a pump is designed. In addition to thinking about being automated, reliability that is generated, the system will allow the necessary conditions to ensure the collection of recovered water is as constant as possible.

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It is noteworthy that the system right now is 37.5% efficient, but it could provide more efficient considering the recovery by condensation, subject of another project that can complement and increase the current.

A project to help provide certainty in the recovery of water, using the minimum of energy consumption, is a project to be sustainable, development is not simple, because it requires a systematic series of steps that will ensure controlled behavior system, but once you are applying values and subjected to appropriate mathematical treatment, then the sustainability of the system is ensured.

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