ANN based Automated Irrigation

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Abstract: **Irrigation has always been the backbone of the civilized society since time immemorial. The need to meet one's survival needs civilization to learn and adopt to different agricultural practices and hence irrigational methods. With population increasing at an exponential rate and land areas being curved short to provide lodging for the enormous population, several new and innovative practices have become inevitable for prolonged sustenance for the human race. We need to find and figure out new techniques such that we can use our natural resources to the best of their abilities. Water which happens to be the most pivotal resource for survival is becoming a scarcity these day and we will be in peril if adequate measures are not taken right away. The subject of talk in this paper therefore relates to the above mentioned challenges we have in hand and trying to figure out some better techniques in this technologically prolific age. Although many an innovative techniques have been employed towards Automated Irrigation, they mostly indulge simple ON/OFF based control logic for their operations which come with quite a few limitations and times a good amount of resource is wasted if not monitored properly or timely. Artificial Neural Network can give us a good amount of remedy from the existing problems as it can operate upon the valves and actuators connected to the system as and when required. Taking into consideration of the parameters which play deciding role in irrigation of a particular kind of crop or plantation, we look forward to designing an ANN based MATLAB simulated model which does give much better results than the conventional ON/OFF ones. The system starts from taking signals from various sensors and ends up at giving much better required output from the Final Control Elements.**

Key words: Artificial Neural Network, Automated Irrigation, Sensor Networks, Evapotranspiration.

I. INTRODUCTION

Among the most basic requirements of life, food occupies the highest position and in order to need this demand for the mass, human societies have discovered the art of agriculture and developed it and ameliorated it over the age. Studies show that improper irrigation techniques lead to waste of priceless natural resources and also lead to inferior productivity of the crops. Only because of poor irrigation techniques employed in India, the grain productivity rate is about 0.87 kg/m^3 whereas in developed countries, it is about 2 kg/m^3. Therefore automation in the field of irrigation and that too, the better ones is the need of the hour. It prevents the waste of resources, saves money and **made it necessary for human** also give better productivity from the same piece of land thus enhancing its efficacy.

II. CONTROL STRATEGIES

While discussing about control strategies, we do come across two types of control action. One, the simple Open Loop Control and the other one rather the better and the more demanding one, the closed control. What happens in Open Loop Control is that it only works on certain Set Point values. The On-Board sensors from the field feed the controller with the data which gets compared in the Controller section and depending upon the set point values, the FCEs are set On. The main drawback with this kind of control action is that it has No Feedback loop refraining it to make a decision when to stop which at most times leads to wastage of resources. This type of systems either have to be turned down manually or a timer has to be put into place which trips off the FCEs after a predefined time delay.

The more preferable control strategy is the Closed Loop Control action which has an additional feedback network enabling the controller to Auto stop the FCEs when the demand for the resource viz. water is fulfilled. For proper and the most optimized irrigation procedure and to yield the possible results, there are several parameters to be considered, both static (fixed) and dynamic (time dependent) parameters. Some of the fixed parameters at any specific point of time are enumerated as follows:

- Type of soil (texture)
- Status or stage of growth
- Salinity of the soil (determining the sweating of the soil)
- Nature of plantation
- Leaf coverage (transpiration and evaporation determining factor)
- Water requirement

Based on the above set of parameter, few input parameters to be considered are

- Soil humidity level
- Ambient temperature

- Breeze speed
- Radiation

In order to design a control logic, all the above mentioned parameters have to be considered and hence the output parameters can be set which are

- Opening / Closing of the valves and / or fertilizers and adjusting their amounts in combination.
- Switching on / off the energy systems (airing, lighting and heat exchanges)
- Opening / Closing of the roof in case of Greenhouse agriculture.

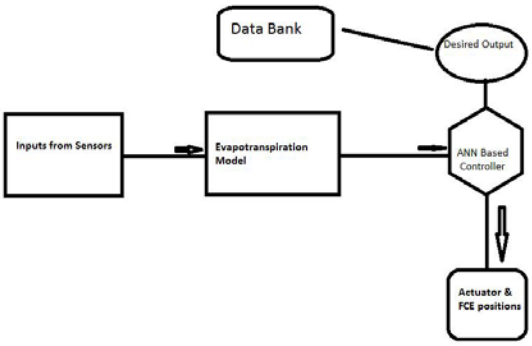

Fig. 1: System Block Diagram

III. EXCOGITATION OF ANN CONTROLLED IRRIGATION

System
Before we start off with any design techniques employing ANN, we need to know what is ANN and why should we involve such a technique in our work. In simple terms it may be defined asan artificial“ neuron network (ANN) is a computational model based on the structure and functions of biological neural networks. Information that flows through the network affects the structure of the ANN because a neural network changes - or learns, in a sense - based on that input and output.it processes information using a connectionist approach to computation. ANNs are considered nonlinear statistical data modeling tools where the complex relationships between inputs and outputs are modeled or patterns are found.

What Are Their Advantages Over Conventional Techniques?

Depending on the nature of the application and the strength of the internal data patterns you can generally expect a network to train quite well. This applies to problems where the relationships may be quite dynamic or non-linear. ANNs provide an analytical alternative to conventional techniques which are often limited by strict assumptions of normality, linearity, variable independence etc. Because an ANN can capture many kinds of relationships it allows the user to quickly and relatively easily model phenomena which otherwise may have been very difficult or impossible to explain otherwise.

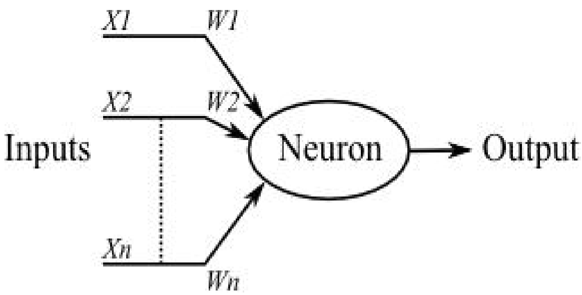

Figure 1 exhibits the block diagram of Complete Irrigation System embedded with ANN Controller. There are four stages connected together to fulfill the requirement.

- Sensortemperature,Input:airhumidity, soil moisture, wind speed and radiation are collected.
- EvapotranspirationfourModel: T input parameters into actual soil moisture.
- Required Soil Moisture:

- ANN Controller:comparestherequired soil moisture with actual soil moisture and decision is made.

3.1 Modeling of System Parameters**:**

Inputs Parameters: There are four factors (Temperature, air humidity, wind speed and radiation) bywhich evapotranspiration is influenced.

3.1.1 Temperature:

- A sine wave with amplitude

•A frequency of 2pi/T=2pi/24. 24 hour time period.

- A constant(offset)of30 ºC;bias

3.1.2 Air humidity: It is modeled as:

- A sine wave with amplitude
- Bias of 60% (constant);

•A frequency of 2pi/T=2pi/24. 24 hour time period.

3.1.3 Wind speed:

- A sine wave with amplitude
- Bias of 3.5 Km/h (constant)

•A frequency of 2pi/T=2pi/24. 24 hour time period.

3.1.4 Radiation: It is modeled as maximum possibleradiation at earth's

- A sine wave with amplitude
- Bias of 112MJ/m;

- A frequency of 2pi/T=2pi/24. 24 hour time period.

3.2 Soil Moisture:

Depends on plantation ,type of growth ,type of land and type ofsoil. The required soil moisture is calculated according tothe above mentioned factors. An assumed graph is shown in figure3.

3.3 Evapotranpiration Model:

Penman-Monteith equation is a equation accepted as a scientifically sound formulation for estimation of reference evapotranspiration (Et_o). it is a combined function of radiation, temperature, humidity and wind speed. Updated by FAO in May 1990, the Penman Monteith equation is written as the following:

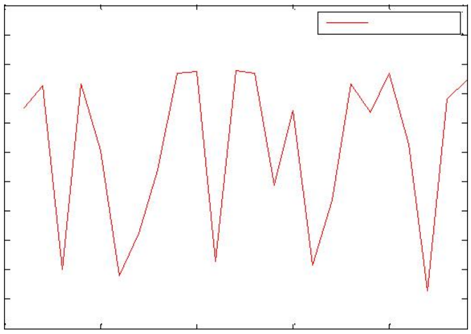

Figure3: Required Soil Moisture-graphical representation.

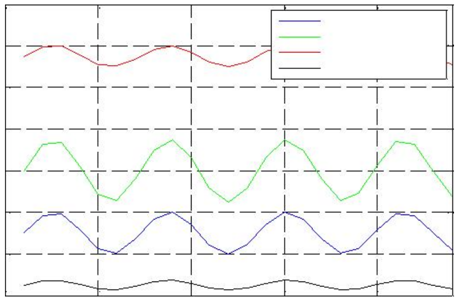

Figure2: Input Parameters: Graphical representation

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)} \quad \text{(a)}$$

$$\Delta = \frac{4098 e^0(T)}{(T+273.3)^2} \quad \text{(b)}$$

$$e^0(T) = 0.6108 \exp\left(\frac{17.27T}{T+273.3}\right) \quad \text{(c)}$$

$$\gamma = \frac{C_p P}{\varepsilon \lambda} \quad \text{(d)}$$

ET_0 = Reference evapotranspiration [mm day-1], R_n= Net radiation at the crop surface [MJ m-2 day1],

G = Soil heat flux density [MJ m-2 day-1],

T = Mean daily air temperature at 2 m height [°C],

U_2= Wind speed at 2 m height [m s 1], e_s= Saturation vapor pressure[kPa],

ea= Actual vapor pressure [kPa],

es-ea= e^0(T) =Saturation vapor pressure deficit [kPa],

D = Slope vapor pressure curve [kPa °C-1],

g = Psychrometric constant [kPa °C 1].

P = Atmospheric pressure [kPa],

z = Elevation above sea level [m],

e^0(T) = Saturation vapour pressure at the air temperatureT [kPa],

λ = Latent heat of-1],vaporizati

C_p = Specific heat at constant pressure, 1.013 10-3 [MJkg-1 °C-1],

ε = Ratio molecular weight o=0.622

3.4. Control Unit:

The control unit is an Artificial Neural Network based controller. Required moisture level and measured moisture level are interfaced with this controller. The main function of this stage is to keep the actual soil moisture close to the required soil moisture. The output of this stage is controlled input for valve to supervise what amount of water to supply to optimize the situation. The simulink diagram of ANN based control system is given in figure 4.

Dynamic Artificial Neural Networks are more powerful than static networks because dynamic networks have memory and can be trained to learn sequential and time varying patterns.

The controller has two inputs i.e. required soil moisture and calculated soil moisture from evapotranspiration model and one output, control input for Valve position.

ANN Controller Architecture:
ANN Controller is implemented using the following:

- **Topology:** Distributed Time Delay Neural Network is used ;
- **Training Function:** Bayesian Regulation function is used for training.
- **Performance:** Sum squared error is taken as performance measure.
- **Goal:** The set goal is 0.0001.
- **Learning Rate:** The learning rate is set to0.05. (Figure 6).

The block diagram of ON/OFF controller is shown in figure 5. Valve opens when required soil moisture exceeds the measured soil moisture and otherwise.

SIMULATION RESULTS

Once the neural network is trained, it can be used as direct controller in cascade with the Evapotranspiration model.The control target is to bring the actual soil moisture as close as possible to required soil moisture and to optimizethe resources like water and energy.

Keeping the aforementioned requirement in mindbehavior of ANN controller is noted for reference (Required) Soil moisture. The Response of ANNcontroller is compared with ON/OFF controllerimplemented with the same evapotranspiration model.This is shown in figure 7-8.The important facts that canbe extracted from the simulations are:

4.1 ON/OFF Controller

The legends of figure7 are:

- Yellow–RequiredsignalSoilmoisture
- Blue-actualSignalsoilmoisture.
- LightRedsignal –valve output.

1. In ON/OFF control based system, the actual soilmoisture tracks the required soil moisture but there are continuous oscillations around therequired soil moisture.

2. The Continuous oscillation at the output shows that the ON/OFF control based system is notstable.

In ON/OFF controller the valve is opened and closed continuously at the extreme points(0 and 10).Due to this, lot of energy and water are consumed which is undesirable.

4.2 ANN Controller:

The legends of figure 8 are:

•Yellow signal-Required Soil moisture

- Light - ActualRedSoilsignalmoisture
- Green-Valveoutput.

The actual soil moisture tracks the required soil moisturewithout any oscillations.

1. The error(difference between required and actualsoil moisture)is steady and reasonable (less than2%)

2. In ANN controller the ON/OFF of the valve andenergy system is very low and hence lot ofenergy and water can be saved.

The main goal of designing the cost-effective and resultoriented Irrigation Control System has been achieved byusing ANN Controller.

CONCLUSIONS AND FUTURE WORK

This paper is a comparative study between ON-OFF control and its ANN controller counterpart. The efficiency and response are much better. The best part of it is that it does not require prior knowledge of system and can be trained on demand and is able to adopt to the changes of the ongoing process. The results obtained are by far more superior than the previous one. It is noteworthy that ANN based systems can save lot of resources (energy and water) and can provide optimized results to all type of agriculture areas. Using the obtained result in real life scenario and thereafter designing its hardware implementation is the future scope of advancement.

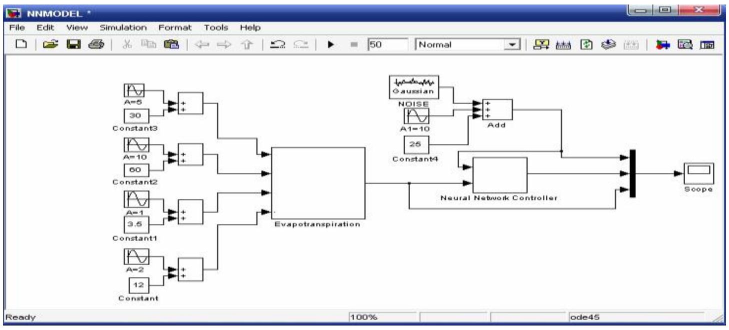

Figure4: ANN based Control System with Evapotranspiration model

Figure5: ON/OFF based Control System with Evapotranspiration model

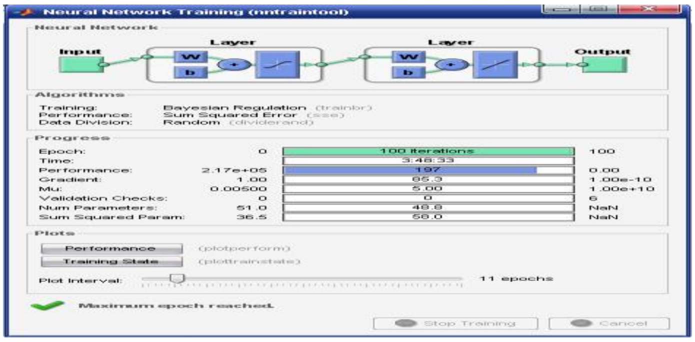

Figure 6: Neural Network Training

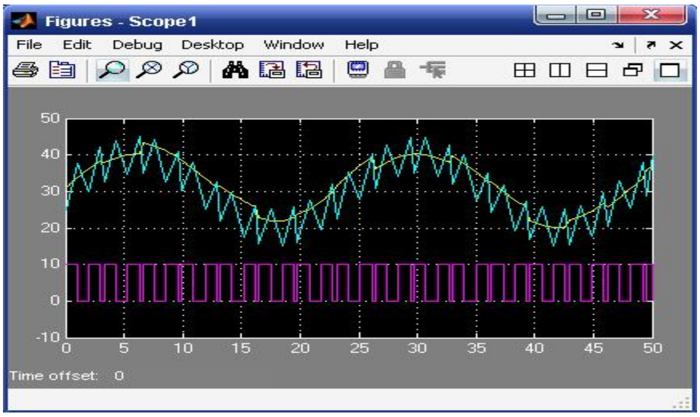

Figure 7: Simulation Results of ON/OFF control based System

Figure 8: Simulation Results of ANN based control System

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