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Smart Irrigation System Using Wireless Sensor Network

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Abstract

This paper presents the design of a model of an irrigation system based on wireless sensor network (WSN). The user-controller provided with information from the receiver board (master) that transmitted sensors data (as current parameter of the plant) through the transmitter board (slave). The receiver board AT89C51 used to receive a real time sensor data from a transmitter to a PC monitor via serial connection and forming a database for future uses. Matlab/ Simulink and Neural Network used for the control system to improve the performance.

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1. Introduction

Wireless sensor network has been under rapid development in agriculture for optimal use of land and water resources. Environmental monitoring using (WSN) in agriculture for collecting data and controlling will give the best crop condition, increase production efficiency, decreasing cost and provide a solid base for farmers to adjust their strategies at any time. There are many designs of irrigation system considering the energy used and water management. Energy used by pumps and valves frequently exceed the energy used for all plants and this will need to look for a selecting of pump with the greatest possible efficiency to reduce energy consumption. The new water management focuses on using intelligent control of valves and pumps during irrigation for competing demands for water and seeks to allocate water on an equitable basis to satisfy all uses and demands. Intelligent systems used to achieve robustness, tractability, and provide a low cost solution with a tolerance of imprecision, partial truth, uncertainty, and approximation. K. Shinghal, et al [1], designed an intelligent sensor using a conventional sensor and embedded processor that can process the data acquired using an algorithm to reduce and extract the data for relevant information, then, presented the information as a vector to minimize post-processing latency. M. Miskam, et al [2], described the preliminary layout on the evolution of WSN to monitor paddy rice cropping. The main objective of the design architecture is to cater the most important and critical issue in WSN, that is power consumption. The proposed wireless sensor system communicates with each other using lower and better power consumption for sensor node. D. Martin, et al [3], described a method to estimate the cost of pumping water and the potential for repairing pumping plants at the Nebraska pumping plant performance criteria. The testing of 165 pumping plants indicated that up to 15% of the systems actually performed at a level above the criteria, besides that, produced an average performance rating of 77%, which translates to an average energy savings of 30% by improving performance. H. Mobtaker, et al [4], focused on the amount of input-output energy used in two irrigation systems in baled alfalfa hay production in Hamedan province, Iran, for efficiency of energy consumption point of view. The main investigation of the study divided into two groups, one of them based on the irrigation system on farms as traditional irrigation and the other group based on the modern irrigation system. Total energy used in the whole production life of alfalfa was 821615.19 MJ/ha in the first group and 723254.38 MJ/ha in the second. The average of the input energy consumption was maximum for electricity in both groups of farms. Investigation of energy indices in the two groups of farms showed that the use of water and energy is in good condition in Group II. R. Morais, et al [5], presented the architecture, hardware and software on a platform designed precision agriculture, called MPWiNodeZ. The main feature of the proposed system is a power-management subsystem for recharging batteries up to three sources. It allows the system to sustain operating as a general-purpose wireless acquisition device for remote sensing in large coverage areas, where the power to run the devices is always a concern. S. Jordan, et al [6], implemented WSN application for irrigation control which is low cost, and ensures proper monitoring of the fields, less involvement of human, instantaneous and accurate decision making. There has been many environmental parameters (temperature, humidity, soil moisture, etc.) used in this proposed scheme. The design model continuously logs data of the concentrated area through sensors and based on the values sensed it would be judged as to which it is facing shortage of water. D. Reuter and R. Everett [7], described and discussed an initial review of a neural -fuzzy control system for irrigation. In its current state, the design is not an improvement over the classical timer based system. It uses excessive quantities of water and would probably drown the lawn in less than a week. N. SABRI, et al [8], presented the fusion of artificial intelligence represented by FIS with WSAN for greenhouse climate control. In addition, the longer life operation of network nodes based on the low power consumption presented. R. Jaichandran, et al [9], presented a prototype for automatic controlling and remote accessing of irrigation motor that includes sensor node, controller node and mobile phone. The operation of the proposed design system based on transceiver data via GSM by sensing soil moisture and control of the motor with required soil moisture value. An alert message sent to the registered mobile phone. Purnima and S.R.N. Reddy [10], gave a review of systems based on existing technologies and also proposed an economic and a generic automatic irrigation system based on wireless sensors with GSM-Bluetooth for irrigation system controller and remote monitoring system. Xuemei Li et al [11], described a real-deployment of WSN based greenhouse management which is designed and implemented to realize modern precision agriculture. The proposed system can monitor the greenhouse environments, control greenhouse equipment, and provide various and convenient services to consumers with handheld devices such as a PDA live-in a farming village. Hui Liu et al [12], presented a wireless sensor network prototype with a two-part framework for greenhouses. In the first part, several sensor nodes used to measure temperature, light and soil moisture. A sink node with the embedded terminal based on ARM processor installed indoor together for collecting and transferring data wirelessly to a remote PC using short message service. The other part consists of GSM module and the management software based on a database running on the remote PC.

The work describes the design of a smart irrigation for a real-time sensing and control of water flow according to the status of soil humidity using Bluetooth to maximize plant growth along with saving water, Figure (1). Graphical user interface-based software development in Visual Basic language offered stable remote access to status, conditions, real-time control and monitoring of the variable-irrigation rate.

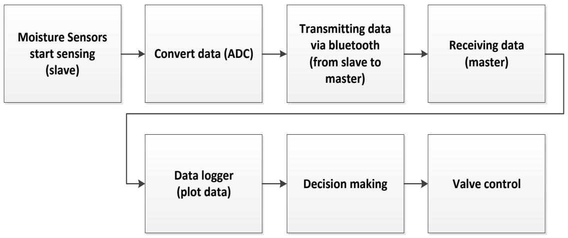

Fig. (1) Conceptual Diagram of Proposed Design

A Neural Network System (ANNs) models attempt to achieve good performance via dense interconnection of simple computational elements and find a function that best map a set of inputs to its correct output Figure (2).

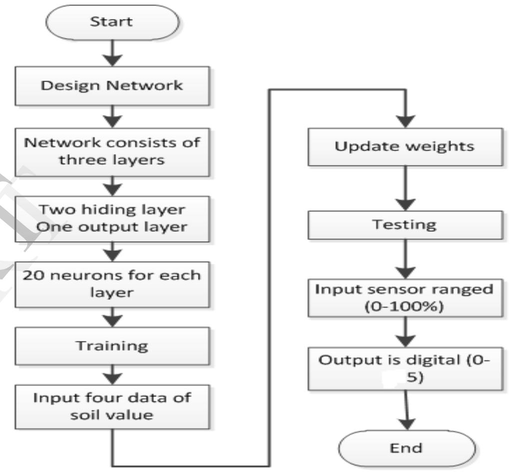

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Fig. (2) Block diagram representation of the procedure of neural network

3-System Description

The smart irrigation design based on hardware and simulation to measure different cases based on the logged data during the test Figure (3).

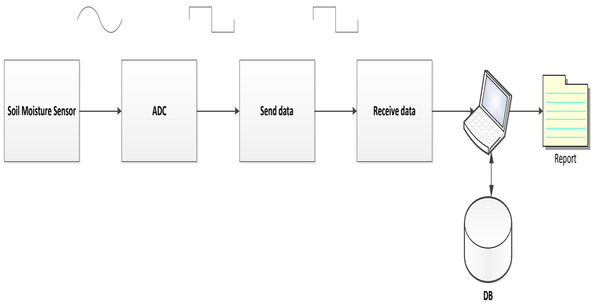

Fig. (3) Block Diagram Representations Procedure of Proposed Work

3-1 Hardware Description

The operation between master and slave started by giving the power, initialization to set parameters, baud rate, bit-stop, and pin configuration that belongs to microcontrollers and then a data sent Figure (4). Once the master received the data, it directly forwards it to the logger (PC) via serial and the process repeated if the program was set for continuous run else the program waits until a disconnect event indicating that the master has disconnected the link of communication.

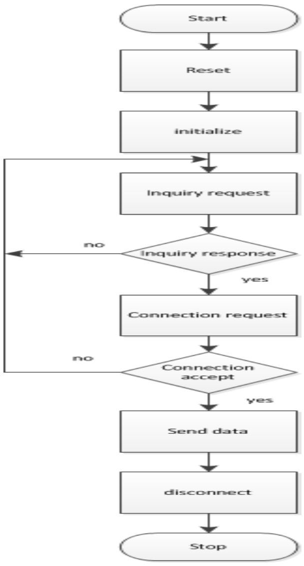

Fig. (4) Master and slave connection flowchart

Two hardwares and programs written, each of the master and slave circuit. A microcontroller (AT89c51), Bluetooth module, and regulators for both Bluetooth and microcontroller are used Figure (5). DAC used to convert the data from the sensor for interface with digital circuit.

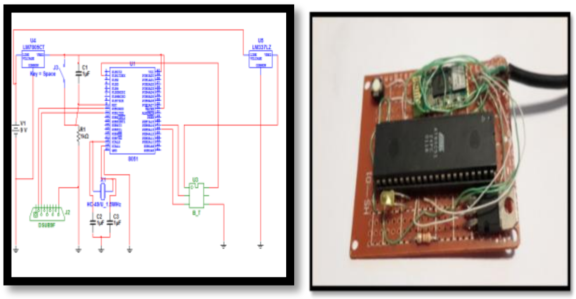

Fig. (5) Master Circuit

A three pin IC used as a voltage regulator in the power supply (5V) to regulate and try to get a constant DC current by connecting the voltage regulator at the output of the filter. The regulator (7805) used in the master circuit to supply the Bluetooth module with 3.3V. The microcontroller AT89c51 has a built in UART for carrying out serial communication. This serial used to establish data transfer between Bluetooth module and an external hardware, which used to receive data via Bluetooth bit by bit while the interfacing serial baud rate is 14400 bps. A Visual Basic program used to control the serial port and components used to control the database. MSComm component often is used to transmit and receive data from communicating devices via serial port, but in our proposed design it is used for receiving data, and the initialization parameters are (baud rate: 9600 bps and pit stop: 1). The electronic circuit for a slave with moisture soil sensors, Bluetooth module, and microcontroller is shown in Figure (6). There are two levels of regulated DC power supply used in this circuit; one supply the Bluetooth module to work on 3.3V, and other on 5V to supply the PIC Figure (6).

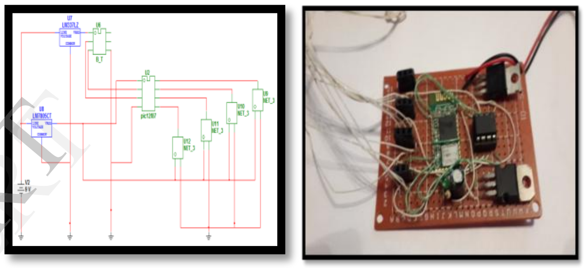

Fig. (6) Slave Circuit

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3-2 Simulation Description

A Matlab Simulink used for simulation of the suggested design hardware. The simulation demonstrates the phases of the whole procedure of suggested hardware design Figure (7).

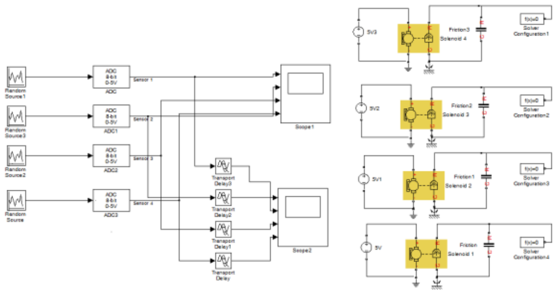

Fig. (7) Block Diagram of Simulation in Matlab

Sensor data will represent the soil dry information (volumetric soil moisture) and the range of sensing, of soil variability based on the location of the sensor, and the mount of dried soil in the sense. A scope block is used to display the results of each input (representing the sensor), as shown in figure (8).

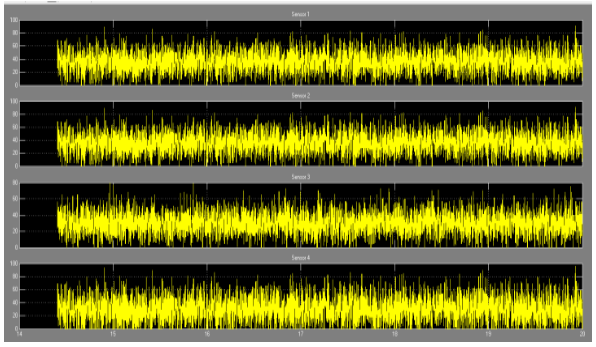

Fig. (8) Signals plot of four sensors

5-1 Results

An experimental result in different cases adopted to test the status of the soil based on different ratios of water, soil volume with four sensors at different levels, to the pots during 1500 min at 40-45 Co room temperature in a sunny day. Two cases consider during updating the data, one with water to the soil volume ratio (40%) and (70%), figures (9 & 10).

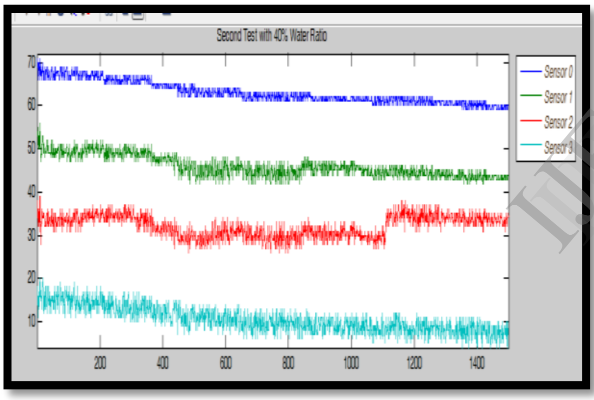

Fig. (9) Percentage ratio of soil, drought for four sensors versus time, soil dry with water (40%)

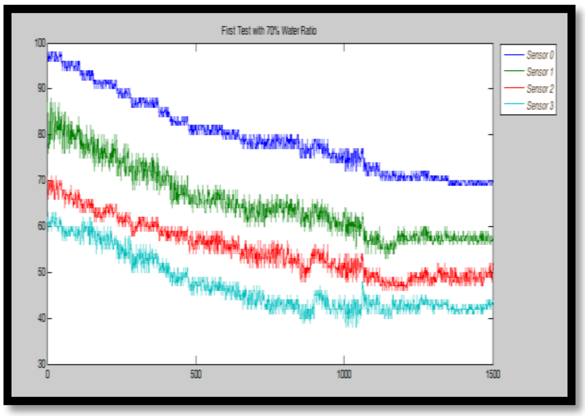

Fig. (10) Percentage ratio of soil, drought with time for the four sensors, soil dry with water (70%)

Different metrics for comparison (MSE, PSNR, and Max Error), for the collected data for the first sensor (1), shown in Table (1). From the results shows 70% water to soil ratio has better values than 40% with less value of MSE for better performance of the estimator (neural network), PSNR of the collected data has high quality and MAX ERROR for 40%.

Table (1) Metric Information of Collected Data

Data Collected	MSE	PSNR	Max Error
40% watered	3.2	42.98	70
70% watered	2.4	44.32	60

NN used to simulate the behaviour of the sensor. The input to the network is the value of the soil moisture with range from (0 - 100%) percent and the output (y) gives the O/P digital value equivalent to the maximum O/P voltage from sensors (5v) with 8 bits, i.e.

$$2^{8-1} = 256 - 1 = (255)$$

This is the decimal value equivalent to 5v max O/P voltage from sensors.

The performance of learning NN to save actual information compared with the desired information shown in Figure (11). The better performance is when the slope is near (1).

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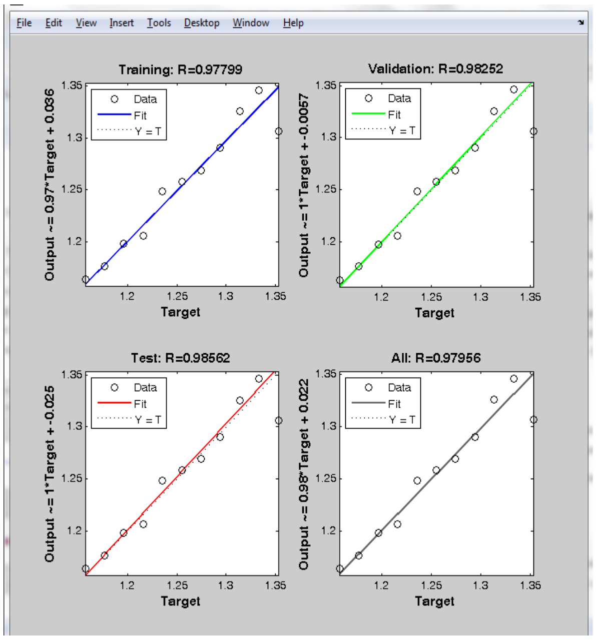

Figure (11) NN testing results

Figure (12) below shows MSE of best validation performance.

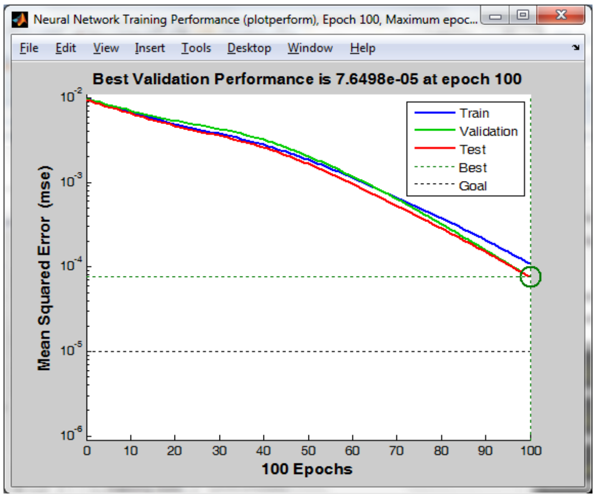

Figure (12) best validation performance

This curve reflects the global performance of NN to simulate the physical system and this factor (MSE) known as the mean square of error between the O/P of sensors currently measured with the desired read values.

Figure (13) shows the training state plot. This plot shows the progress of the training variables:

Gradient magnitude (change of weights with error, $\frac{\partial W}{\partial E}$)

The number of validation checks (factor used for training and testing NN, which shows the reliability of work of NN, this factor is very small and error rate reaches a small vial with epochs learning)

Learning rate (training parameter that controls the size of weight and bias changes during learning).

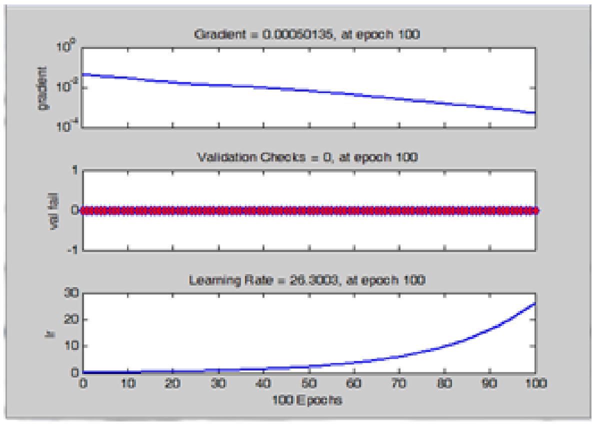

Fig. (13) Training state plots

In real-time the automated data logger used to collect data, in the simulation, as signals representing the reading of the sensors to control the solenoids.

Figure (14) and table (2), Shows the sample of collecting data in real-time and simulation.

Table (2) Collected Data during real-time and simulation

Time (t)	Real-time	Simulation
6:58:40 AM	71	81
6:58:42 AM	69	90
6:58:44 AM	70	92
6:58:46 AM	66	58
6:58:49 AM	70	97
6:58:51 AM	67	98
6:58:53 AM	69	95
6:58:55 AM	71	90
6:58:57 AM	66	71
6:59:00 AM	68	87

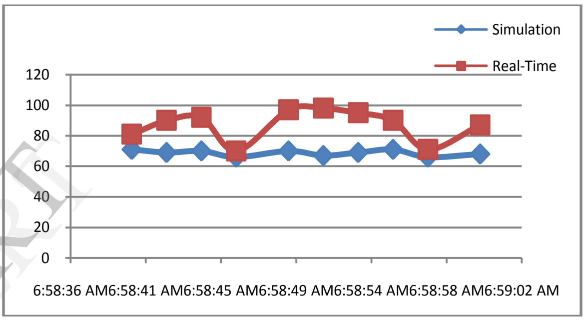

Fig. (14) Sample of collecting data for both real-time and simulation

Another result found from the analog to digital to describe the volumetric measurement of soil, drought voltage (0-5v) when converted to digital as shown in figure (15).

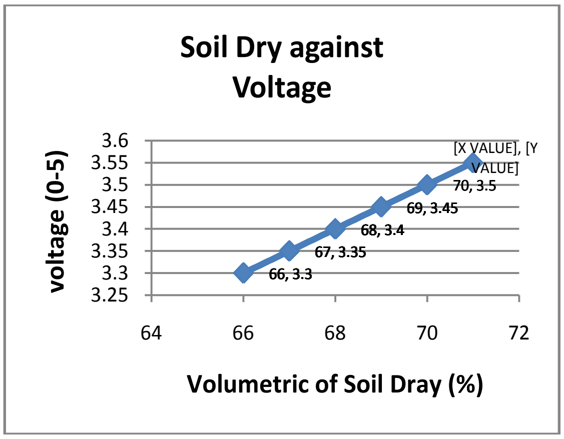

Fig (15) represents soil dry against voltage

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6- Conclusion

The design and the implementation of an autonomous soil moisture monitoring system, which comprises of a wireless sensor network and Bluetooth interfacing, presented in this paper. The main consideration in the present Smart Irrigation System, based on water, soil automation, Wireless sensor network (WSN). A Bluetooth technique for transceiver data from slave to master, monitoring, save data, display the variation of water, soil conditions in real-time, a computer simulation design in in addition to Neural Network to improve the performance of controlled watering method considered. Different types of sensors for temperature, humidity, etc., with internet-based remote control of irrigation automation and transfer fertilizer and the other agricultural chemicals (calcium, sodium, ammonium, zinc) to the field with new sensors and valves can use in the suggested design.

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