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Solar Powered Irrigation Management Based on Parameter Sensing and Weather Forecasting using BPN Decision Making with IOT

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Abstract: Automated irrigation scheme is essential for the conservation of water and also proper growth of crops in agricultural farms. The proposed scheme consists of sensors for soil moisture detection, quantifying the leaf wetness level, detection of humidity and temperature in the farm area. This scheme also incorporates crop details, soil type and weather forecasting details to decide if watering is essential on the particular day or not. Sensor and weather forecasting information are the deciding factors in the Back Propagation Neural (BPN) network based decision making process. The results of BPN based control action is automated by IOT based Arduino microcontroller system to turn on the irrigation pump for discharging required quantity of water. It also automates the solar power available for driving the pumps when they run during the day time. This module also comprises the warning system regarding when to use insecticides and pesticides based on the humidity and temperature around the crops.

Keywords* — *IOT, BPN, Solar Power, Arduino, Weather Forecasting, Irrigation Automation, Sensors

I. INTRODUCTION

In developing countries most of the irrigation systems are operated manually. These conventional irrigation systems are based on irrigation timetable, which is different for different crops and dependent on type of soil and other parameters. This resulted in excessive labour and no-uniformity in water across the field. Traditional manual methods results in a lot of water wastages and can also promote diseases such as fungus formation due to over moisture in the soil. Efficient irrigation in the farms depend on environmental factors like moisture, humidity and temperature, type of the crop cultivated, soil texture and the weather condition. Hence smart automatic irrigation system based on sensing technology is required for optimum usage of water resources [1].

Methods proposed in the past few decades were aimed for improving the efficiency of water use in large scale irrigation arrangements in which the goal was to control, not manage water [2]. Sometimes large infrastructure water management interventions are not the best investment. The motor pump ON and OFF is supervised by valves in automated irrigation system. The controllers automatically control the valves easily. In the literature, some methods were proposed to discharge exact quantity of water at proper time independent of the availability of labor to switch the valves. over watering saturated soils are reduced by farmers using automation equipment, and irrigating is avoided at the improper time of day, which will improve crop yield by providing required amount of water and nutrients when needed [3].

Wireless sensor network technology has a wide-ranging application in several areas because of its advantages such as reliable data transfer, flexible network, affordable equipment, long battery life, etc. The enactment of modern control irrigation for crop water is one of the best way to improve the utilization of water. Wireless Sensor Networks are extremely useful in applications that involve monitoring of real-time data. In order to enhance the yield and the use of the available resources, wireless sensor networks can play a significant role because of their ability of providing real-time data collected by distributed sensors.

The term Internet of Things (IOT) is principally used for devices that wouldn't be expected to have an internet connection, and that can able to communicate with the network independent of human command. This makes IOT is an integral component of several automated irrigation schemes [4]. The success of any automated irrigation scheme relies on the decision making parameters and the effectiveness of the decision making system. Domain knowledge and technical expertise is essential for designing such system [5].

In this proposed scheme, the decision making parameters are soil moisture, crop type, atmospheric pressure and temperature, leaf wetness percentage and week ahead weather forecast information. Some parameters are sensed and feed to Arduino microcontroller. This information is transmitted to the remote control Center through Wi-Fi and IOT technology [6].

In the remote center, Back Propagation Neural [9,10] Network based decision process is carried out with the

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sensor data, weather information feed and farm data. The control signal is send to the Arduino system which regularizes the operation of the motor pump. BPN is trained with historical data related to the problem domain.

II. Parameters Based Irrigation

Water requirement of farms depends on type of the crop, soil texture, soil properties like moisture, humidity and temperature, and the weather condition [7]. Soil moisture sensors are placed based on the rooting depth of Crops which is tabulated in Table 1. Table 2 presents the Available Water Storage Capacities (AWSC) of different soils. It is the quantity of water that can be stored in the soil. Plants are capable of extracting only a portion of the water from the soil before being stressed.

Table 3 gives the maximum water absorption capability of different crops. Water content or moisture content is the quantity of water contained in a soil called soil moisture. The soil moisture sensing bounds are indicated in table 4. Environment temperature conditions related to the plant area are depicted in Table 5.

Table 1: Effective Rooting Depth of Different Crops

Crop Name	Rooting Depth in ft
Cabbages, Cauliflowers, Cucumbers, Lettuce, Onions, Pasture, Grasses, Radishes, Turnips	1.5 ft
Beans, Beets, Blueberries, Broccoli, Carrots, Celery, Potatoes, Peas, Strawberries	2 ft
Brussels Sprouts, Cereals, Clover (Red) Corn (sweet), Eggplant, Kiwifruit, Peppers, quash	3 ft
Alfalfa, Asparagus, Blackberries, Corn, Grapes, Loganberries, Raspberries, Beets	4 ft
Mangoes Tree and other Tree Fruits	>4 ft

Table 2: Soli Water Storage Capabilities

Soil Texture	AWSC [Inch(W)/Foot(S)]
Sand	1.0
Loamy Sand	1.2
Sandy Loam	1.5
Fine Sandy Loam	1.7
Loam	2.1
Silt Loam	2.5
Clay Loam	2.4
Clay	2.4
Organic Soils (muck)	3.0

Table 3: Plant Water Usage Capabilities

Crop Name	Plant Water Use Capabilities (%)
Peas, Potatoes	15
Tree Fruits, Grapes, Tomatoes…	30
Other crops	35

Table 4: Soil Moisture Content levels in CentiBars

Sensor Moisture Content	Soil Moisture Level (CentiBars)
Saturated	10
Adequately Wet	20
Normal	30
Dry	40

Table 5: Environment Temperature *in* $^{\circ}$C

Environment Temp. in $^{\circ}$C	Condition
10	Very Cold
20	Cold
30	Normal
40	Hot
45	Very Hot

Table 6 indicates the Relative Humidity. Relative humidity is the percentage of maximum water content at a given temperature.

Table 6: Environmental Humidity levels

Environment Relative Humidity in %	Condition
10	Low
20	Medium
30	High
40	Extremely High

Table 7 shows Leaf wetness condition (LWS) usually the output which is measured in mV ranges between 100–1500 mV @ 3V excitation. LWS is a leaf-wetness sensor that can detect small amounts of water or ice on the sensor surface.

Table 7: Leaf Wetness levels

Leaf Wetness in mV	Condition
100	Wilting
400	Normal
500	Frost
700	Dew
1000	Rainfall

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III. METHODOLOGY

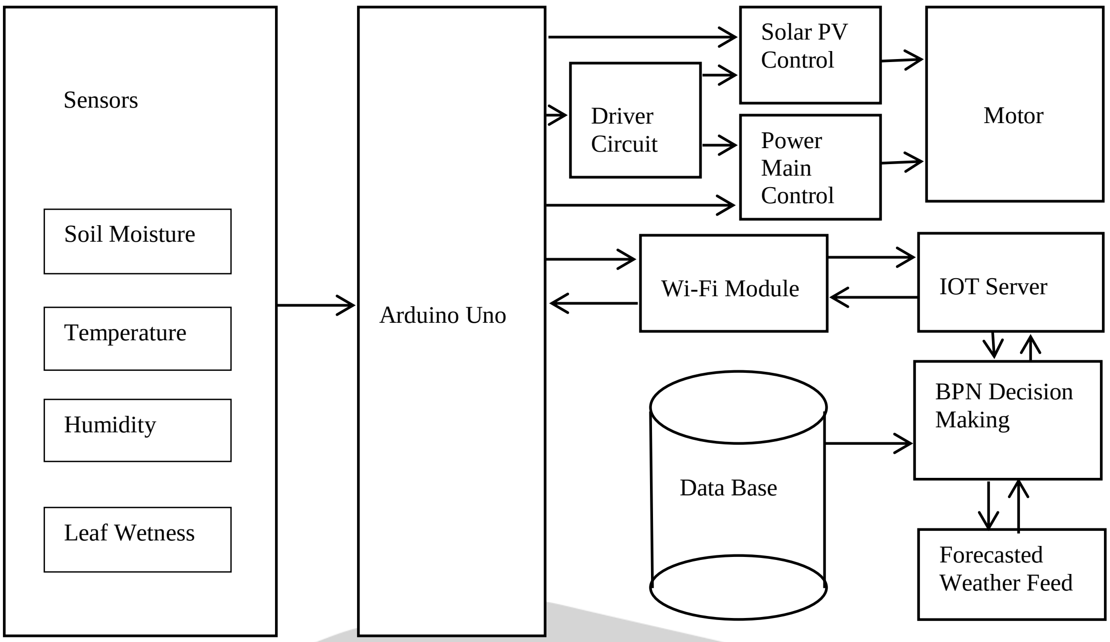

Fig. 1.Block Diagram of Proposed Methodology

Automation mechanism enhances motors operation by controlling the on and off time for discharging the required quantity of water for various regions of a farm. In this scheme, soil moisture sensor, temperature sensor, humidity sensor and leaf wetness sensors are connected to the Arduino microcontroller. These parameters are transmitted to the remote control center through Wi-fi and IOT. This methodology proposes weather information is the one of the vital parameter in the decision process. BPN neural network is trained in the remote terminal using various soil parameters, crop information and different weather condition. The BPN based decision making process results ON/OFF timing of different motors at different regions of the farm for irrigation. It also controls the power supply to the pumps that may be solar power available at that area or conventional grid power.

This information is send to the microcontroller system to initiate the necessary control action. Decision making process also presents a warning regarding when to use insecticides and pesticides based on temperature and humidity around the crops. The schematic of the proposed scheme is shown in Figure 1.

A. Soil moisture sensing

Copper electrodes are used to measure the moisture content of soil. The conductivity between the electrodes helps to quantify the moisture content level. The conduction through electrode varies with content of water absorbed by gypsum. In wet condition, its resistance becomes 100K hence the output from comparator is -Vsat indicating normal wet condition. When the dry condition is appeared in the field, its resistance value is 10K and thus the drop at the non-inverting terminal than that at the inverting terminal. The output +Vsat indicating a dry condition of the soil.

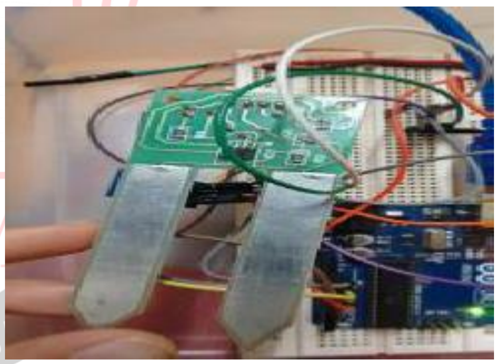

Fig.2. Soil Parameter Sensing

B. Environment Temperature and Humidity Sensing

The LM-35 temperature sensor is used in the proposed system for sensing the temperature. Op-Amp IC-741 is used as a differential amplifier which is the arrangement of both inverting and non-inverting amplifier. The amplifier output is in terms of mv. The temperature sensor measures the environment temperature in degree Celsius which is converted into mv. One degree Celsius is equal to 10 mv.

Humidity sensor SY-HS-2 measures the relative humidity in the range of 0 to 100 percentage. These capacitive relative humidity sensors typically uses an industrial proven thermoset polymer, three-layer capacitance construction, platinum electrodes and, low and medium temperature versions have on-chip output voltage signal conditioning facilities.

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C. *Leaf Wetness Sensing*

Diseases caused by fungus and bacteria affect plants when there is moisture content on a leaf surface. The leaf wetness defines the presence and duration of canopy wetness allowing users to forecast disease and protect the plant canopy. The Decagon Sensor outputs 445 raw counts during dry condition. During total wet condition, it is around 1400 counts. Sensor output is proportional to the amount of water varied on the sensor's surface.

D. *Arduino Microcontroller System*

Sensors outputs and motor controlling circuits are connected to the I/O pins of Arduino Uno controller. The Uno Microcontroller board is based on ATMEGA 328P. The ATMEGA 328P has 32kB of flash memory for storing code. It also has 2 KB of SRAM and 1 KB of EEPROM for good processing speed. The board has 14 digital I/O pins, 6 Analog inputs, 16 MHz Quartz crystal, USB, ICSP circuit, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a bytes-oriented 2-wire Serial Interface, an SPI serial port, a 6-channel 10-bit ADC and a reset button [8].

E. *Wi-Fi Module*

ESP8266 Wi-Fi module is a self-contained System on Chip with integrated TCP/IP protocol stack that can give any microcontroller access to any Wi- Fi network. Each ESP8266 unit comes with preprogrammed meaning; it can be easily connected to Arduino device to acquire Wi-Fi ability. This module has a powerful on-board process and high capacity of storage that permits it to be integrated with any application specific devices.

F. *IOT*

The term Internet of things (IoT) is generally proposed for devices that wouldn't traditionally expected to have an internet connection, and that can able to communicate with the network independently of human action. The IoT is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enable these things to connect, collect and exchange data.

In this automation, micro controller along with sensor inputs and motor control are connected to the IOT server. IOT server receives sensor output parameters form the fields and weather data from the metrological server. It already had data related to crop type, soil type and water requirement for a crop pattern. It feeds this information to the BPN system and gets the decision related to the control of motor pumps in the farms. Then these control actions are realized by the Arduino based hardware in the farm. The server side management is also an automated procedure.

G. *Back Propagation Neural Net Based Decision Making*

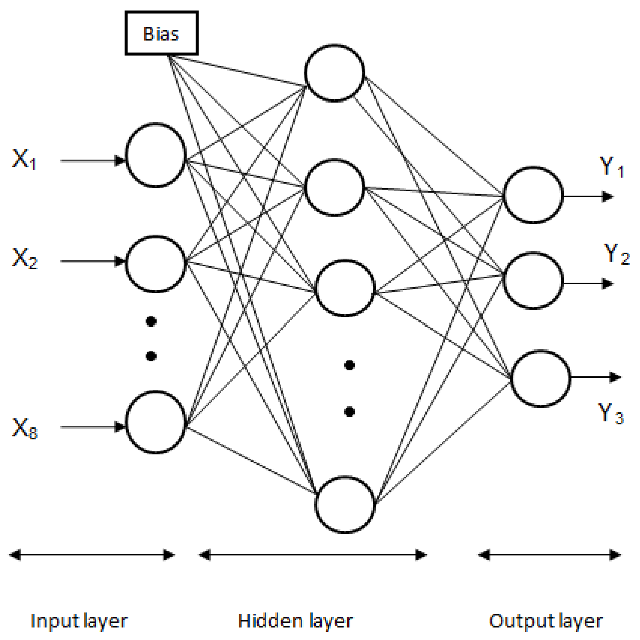

Fig.3. BPN Architecture for Decision Making

Irrigating motor pumps are controlled based on soil moisture content, leaf wetness, temperature and humidity of the environment, type of the soil and crop, weather forecast of that region and motor running at whether day or night time. BPN decision system incorporates these parameters. Soil parameters are transmitted from Arduino system. Soil and crop type information are retrieved from the database. Week ahead weather forecasting information is received from meteorological system server.

Proposed BPN system has 8 neurons in the input layer, 24 neurons in the hidden layer and 3 neurons in the output layer. Binary sigmoid activation function and Levenberg–Marquardt algorithm are employed in this decision process. BPN is trained using historical data considering all weather condition. Each neuron in the input layer represents sensed parameters, soil and crop information and weather forecasting details. The output belongs to control action related to motor pumps such as ON time and whether power input to the motor is from solar or grid. This BPN model is realized in Matlab platform at the remote computer in the IOT server Centre.

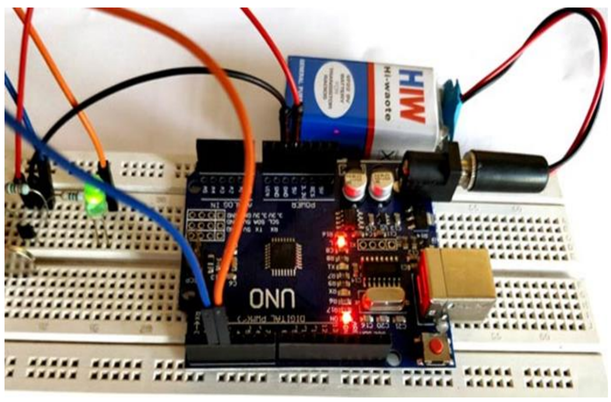

Fig.4. Automated Irrigation Scheme- Hardware

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IV. Discussion

Water is automatically irrigated to the crops and once the required amount of water is discharged, the microcontroller system stops the pump. Precision in irrigation is achieved with reliable sensing and the certainty in weather forecasting. Domain knowledge regarding the agricultural practices also plays an important role in the training of BPN. BPN system can be periodically trained with the experience gained in every season. This can be performed by the expert at the remote control center. Proposed approach sofasticates the irrigation process than the schemes presented in the literature by not only considering parameters related to the farm area but also by processing the weather forecating information available. It also integrates the local solar power resources for driving the electrical motors. These features improve the irrigation system and also achieve precision in irrigation management of agricultural farms.

V. Conclusion

An automated irrigation scheme for agricultural farms with IOT based BPN decision process is presented in this paper. This methodology incorporates weather forecasting in the farm area for precise irrigation which is not considered in the literature so far. Sensor and weather forecasting information are the deciding factors in the BPN decision making process. The results of BPN based control action is automated by IOT based Arduino microcontroller system by turn on the irrigation pump to discharge required quantity water. It also integrates the local solar power resources for driving the electrical motor pumps. This module saves man power, reduces wastage of water and aides the growth of crops by supplying right quantity of water at right time by complementing technical advancement and domain knowledge.

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