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Smart Farm Using Wireless Sensor Network for Data Acquisition and Power Control Distribution

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Abstract — **Smart Farming makes a tremendous contribution for food sustainability for 21st century. Using wireless sensor network in farming from; independent power source distribution, monitoring valves and switches operation, and remote area control will efficiently produce excellent quality farm products in all season. In order to control farm power distribution and irrigation system, this paper proposes a communication methodology of the wireless sensor network for collecting environment data and sending control command to turn on/off irrigation system and manipulate power distribution. The simulation results shows that the proposed system developed is accurate robust and reliable.**

Keywords—wireless sensor, communication network, smart farm, power distribution.

I. INTRODUCTION

Adopting the global warming into agriculture is very challenging. Smart Farming using Wireless Sensor Network leads the answer for this challenge. The purpose of this research is to apply the wireless sensor network and to create its communication methodology to over come the effect of global warming into farming industry. Also, to give long term sustainability of quality fruits and vegetables supply.

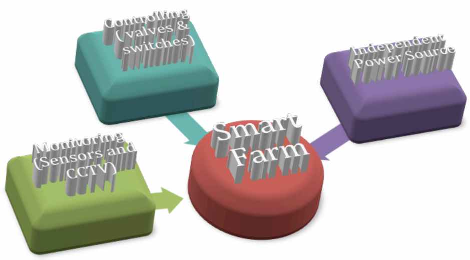

Figure 1. Block Diagram of Smart Farm

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The interest of Smart Farm in this study is that it can be applied to any variety of fruits and vegetables in any remote area. In this study the smart farm has three major components: 1.) *Monitoring* (CCTV for actual environment of farm and image processing of the development/disease of plant, Sensors for data acquisition of plants and environment, control system and power distributions); 2.) *Controlling* (electronics valves for irrigation and electronic switches for smart power distribution); 3.) *Independent Power Source* (using solar panels).

Environment real time monitoring and water management are the important things to consider in smart farming. Plant grow are directly affecting by both factor of environment and water management. In smart farm, power management are necessary for the entire system (real time monitoring and water management) in order to maximize the potential of producing quality fruits and vegetable. For energy efficiency to save power for the entire system and for ease decision of smart power distribution, Fuzzy Logic is use to control the power switches. It is necessary to create a hierarchy protocol of prioritization for decision making of power distribution.

Researchers had developed and used various devices for detecting and collecting soil and environment conditions [4]. They had installed the sensor devices and transmission equipment in appropriate area [5]. These sensor devices have used in wireless sensor network (WSN). A case in point is some researcher had studied the reflected of ultrasonic wave signals monitor a soil moisture and groundwater levels [6] to predict the occurrence of landslides and slope. First, they installed an ultrasonic transducer inside steel pipe and take steel pipe buried in the ground then they calculated reflection of the wave period to measure the moisture content of the soil and the water level. That may cause the landslide when heavy rains. Therefore, the study of the measurement and surveillance environment in agriculture has performed extensive research and continuous with the technology to help for detecting the amount of light, humidity and temperature using wireless sensor networks to collect and process on a computer server and report to farmer through mobile device like PDA or cell phone [7, 8]. The environments have various factor relate to plant growth such as temperature, moisture in the air, soil moisture (the water leakage outflow speed of groundwater) [9] and soil PH. Automated Irrigation system has reported factors to farmer through mobile SMS, website[9] or voice mail alert [8]. The part of device to transmit data is often used as a TinyOS or microcontroller (MCU) and ZigBee (XBee) for radio transmission to send data signals from source to destination [11, 12]. Almost all of the system are powered by solar cells and batteries [13].

II. THE PROCESS INVOLVE IN DATA ACQUISITION USING WIRELESS SENSOR NETWORKS

In this section, the researcher describe the sensor devices for collected environment data which communication between Atmel AVR microcontroller (Arduino) and sensors by send and receive of RF signals through wireless communications (ZigBee).

The environment measurement sensors

The researchers developed sensors and MCU to collect data from four type of sensors including soil moisture, air temperature, air humidity and water level for irrigation. These sensors installed on vegetable crop and brought the level of water in the pipe to the MCU for calculating and determining the speed of water flow and leakage in the soil.

1) Process of detecting Air Humidity and Temperature

The researchers explain of how to acquire the temperature and the humidity data of the environment and vegetable crop from DHT11/AM2302 sensor. Figure 2 shows the circuit layout wiring of the DHT11/AM2302 sensor. For information request sending, MCU send the start signal to the DHT11 for changing the AM2302 standby status to running status. After MCU has finished sent the start signal, the AM2302 will reply a response signal of 40-bit data that contains humidity and temperature data back to the MCU. the MCU must send the start signal to the AM2302, Otherwise AM2302 will not give the response signal to the MCU. However, the AM2302 will change running status to standby status when transmission has finished or if it does not receive the start signal from the MCU again. The communication process is shown in Figure 3.

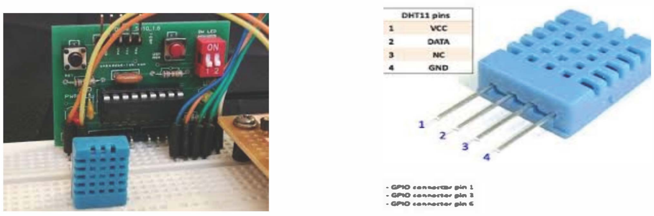
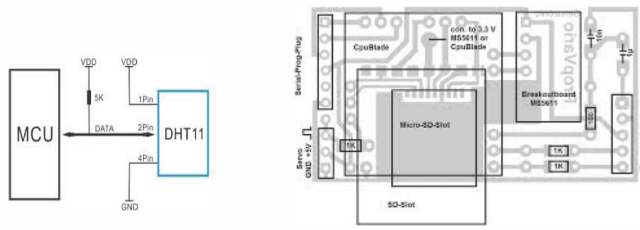


Figure 2. DHT11 Temperature/Humidity Sensor

At these section, the researchers present how the MCU retrieve data from the DHT11 with a single cable. The MCU use a single cable in order to adjust voltage HIGH (5 Vdc) and LOW (0 Vdc) with time step. When the DHT11 status is in standby, the state of the signal data pin is HIGH with Pull-Up. When MCU begin to read, It assign data pin as output pin, and then make start bit by send voltage LOW to sensor at least 80µ sec (Microsecond). Actually it should be 1 ms (1 Millisecond), and afterward the MCU changes the signal to HIGH voltage for 20 sec (Microsecond) and waiting for a reply [1].

Finally, the MCU calculate the differential response values from the sensor. It has to change the signal voltage to LOW for 18 msec and release back to HIGH for 40 µsec, then the DHT11 will send data one by one bit. If value of bit is "0", the sensor will reduce the voltage to LOW for 80 µsec, then change the voltage to HIGH for 80 µsec.



a). DHT11 circuit layout b.) DHT11 PCB layout

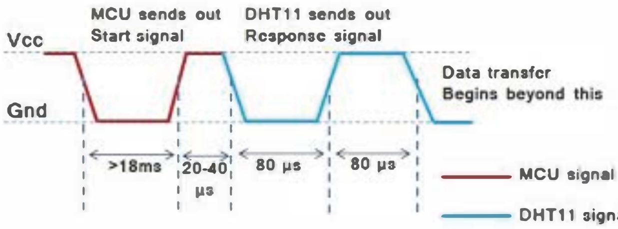


Figure 3. The communication process of DHT11/AM2302

2) The Detection of Soil Moisture and Underground Water Level.

Figure 4. Soil moisture sensor

Relating to plant growth, Soil Moisture is to be considered as one of the most important factor. With the soil conductivity and underground water level, an approximately level of soil moisture can calculated. The surface soil moisture is calculated by measuring the conductivity of soil. Underground water level can measure from electrical conductivity in soil layer of around vegetable roots. We developed the underground water level sensor based on water leakage out of underground pipe.

This sensor use the transistors and the shift register IC to read the electrical signals when electrical current runs through water to parallel input pin of IC. The circuit of underground water level sensor is shown in Figure 5.

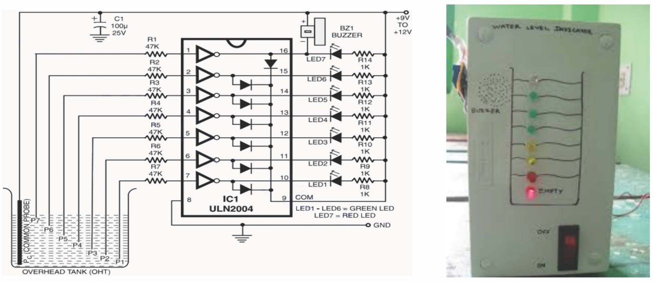


Figure 5. The underground water level sensor circuit

The shift register circuits use for converting the parallel input signal to the serial output signal (Parallel input to Serial output). We use 2 units of CD4021BE IC shift register.

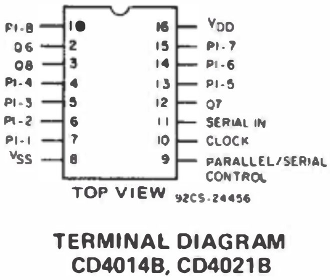


Figure 6. Top View of CD4021BE

Configuring the parallel and serial port communication, the researchers used CD4021BE. Pin 6 and 7 of IC 1 which is PI-1 and PI-2 respectively for are connected to transistor for level 9 and 10 which is the water level measurement that is serial output of Pin 3. The signal has to send at Pin 11 of IC-1 which is serial IN and Pin 1, 4 to 7 and 13 to 15 of the first IC that is connected to transistor for water level measurement from level 1 to 8. Considering Parallel In – Serial Out sequence, shift register is the parallel input connected respectively including flip-flop circuit. Setting latch Pin of the MCU into HIGH condition for 20ms and then setting latch Pin again into LOW condition, mean that MCU tell the shift register that MCU is ready to accept incoming information. Two (2) minutes are required setting time for clock pin to HIGH after the MCU is in ready state.

Next stage was the collection of data from each sensor from the crop yield and power control, this is to be done by MCU. For correct data transmission pattern the MCU will convert in a raw data form. After the environment information was complete and ready to send. MCU will prepare Xbee module and serial communication to send information.

COMMUNICATION ARCHITECTURE FOR WSN

In this section, we describe how ZigBee (XBee Series2) with mesh protocol and AT Command mode can work for communication with each other by the data transmission protocol that uses the word group pattern. A. Data Transmission.

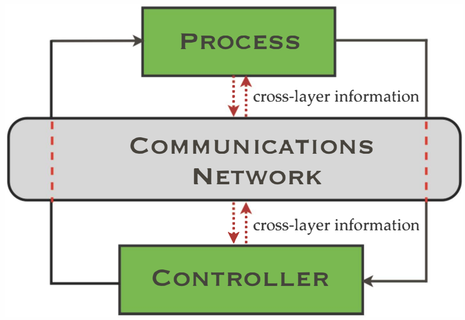


Figure 7. Simple Diagram of WSN

1) Wireless Data Transmission: The communication between each node is the serial communication. The sensor nodes are placed at various points near the vegetable crop area and the coordinator node is placed near the sensor nodes and web server node. Each node consists of the XBee devices. Then, the sensor nodes will send the data to the coordinator node. If the sensor node is out of range from the coordinator node, then they will send the information through another node that can communicate with the coordinator node. The coordinator node process and send commands to control the environment to sensor nodes after it has received data. In the other hand, it sends information to web server node for collecting and reporting the environment information of the vegetable crop area. The communication framework is shown in Figure 9.

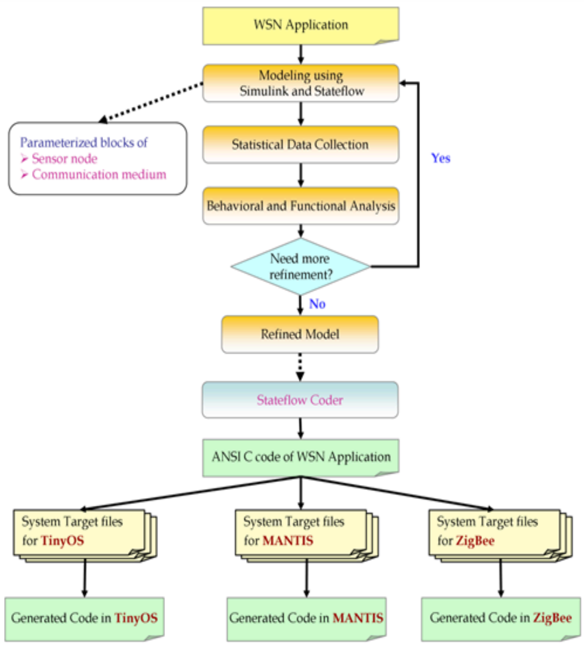


Figure 8. The communication framework

The study focus on the use of Zigbee. ZigBee is a specification that enables reliable, cost effective, low power, wireless networked, monitoring and control products based on an open global standard. ZigBee is targeted at the WSN domain because it supports low data rate, long battery life and secure networking. At the physical and MAC layers, ZigBee adopted the IEEE 802.15.4 standard. It includes mechanisms for forming and joining a network, a CSMA mechanism for devices to listen for a clear channel, as well as retries and acknowledgment of messages for reliable communication between adjacent devices. These underlying mechanisms are used by the ZigBee network layer to provide reliable end to end communications in the network.

At the network layer, ZigBee supports different kinds of network topologies such as Star, Tree and Mesh. The ZigBee specification supports networks with one coordinator, multiple routers, and multiple end devices within a single network. A ZigBee coordinator is responsible for forming the network. Router devices provide routing services to network devices, and can also serve as end devices. End devices communicate only with their parent nodes and, unlike router devices, cannot relay messages intended for other nodes.

2) Model of Data Transmission for Communication within the Network: To receive and send data for wireless sensor network. The data is transmitted via XBee (wireless module ZigBee XBee Series 2). The purpose is to build the WSN system. This system can work either indoors, outdoors and various environments as well. The XBee transmits the signal as the characters through small Chip. It can transfer the data as point-to-multipoint or point-to- point until the destination node has received the data. The XBee transceiver utilizes the Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA) which is the multiple input-output channels to prevent the collision of signals. The network topologies would be a Star, Mesh or Peer-to-Peer.

3) IEEE 802.15.4 Generic Channel Modeling Use by Zigbee

The researcher use the standards for 802.15.4 for energy efficient data communications with data rates between 1kbit/s and several Mbits (MAC). In addition, the capability for geolacation plays an important role. An application for Agricultural areas/farms: for those areas, few propagation obstacles (silos, animal pens), with large distances in between, are present. Delay spread can thus be anticipated to be smaller than in other environments[14].

The pathloss in a narrowband system is conventionally defined as (Eq. 1)

$$PL(d) = \frac{E\{P_{RX}(d, fc)\}}{P_{TX}} \quad (1)$$

where P_{TX} and P_{RX} are transmit and receive power, respectively, as seen at the antenna connectors of transmitter and receiver, d is the distance between transmitter and receiver, fc is the center frequency, and the expectation E{} is taken over an area that is large enough to allow averaging out of the shadowing as well as the small-scale fading E{.} = Elsf {Essf {.}}, where "lsf" and "ssf" indicate large-scale fading and small-scale fading, respectively. Note that we use the common name "pathloss", though "path gain" would be a better description (PL as defined above Due to the frequency dependence of propagation effects in a UWB channel, the wideband pathloss is a function of frequency as well as of distance.

The distance dependence of the pathloss in dB is described by (Eq. 2)

$$PL(d) = PL_0 + 10n \log_{10}(d/d_o) \quad (2)$$

where the reference distance d_0 is set to 1 m, and PL_0 is the pathloss at the reference distance. n is the pathloss exponent. The pathloss exponent also depends on the environment, and on whether a line-of-sight (LOS) connection exists between the transmitter and receiver or not.

To compute the frequency-dependent power density at a distance *d*, as (Eq. 3)

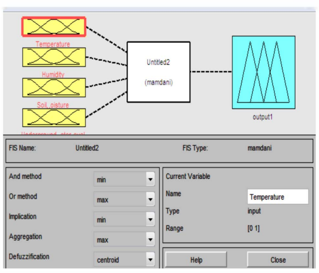
$$\widehat{P}(f,d) = K_0 \frac{P_t(f)}{4\pi d_0^2} \left(\frac{d}{d_0}\right)^{-n} \left(\frac{f}{f_c}\right)^{-2\kappa} \quad (3)$$

where the normalization constant K_0. Note that this reverts to the conventional picture of energy spreading out equally over the surface of a sphere when set n = 2, and κ = 0.

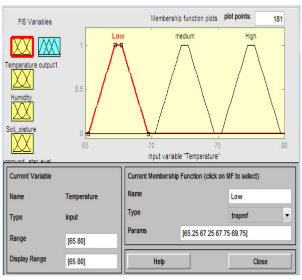
III. EXPERIMENTAL EVALUATION

POWER CONTROL / IRRIGATION SIMULATION FROM WSN

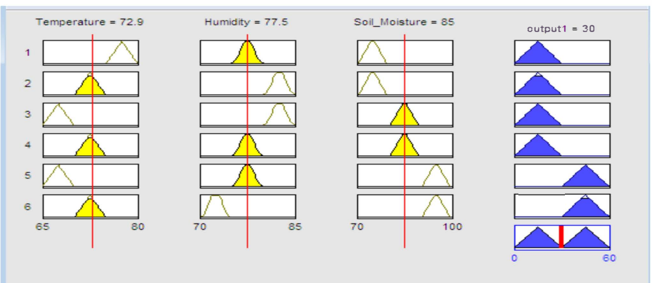
The simulation used MATLAB-Fuzzy Logic for controlling of power control distribution as well as the irrigation. Fuzzy inference systems (FIS) are knowledge-based systems that deal with imprecise or uncertain information. It is derived from the principles of fuzzy logic that is motivated by the human capabilities of making sound decisions despite the imperfectness, imprecision, incompleteness and conflicting information. Fuzzy inference systems are used as decision making unit of process control systems. It uses IF-THEN statements and “AND” or “OR” rule statements for the decision rules. The system consists of a fuzzifier, a knowledge base, fuzzy inference engine and defuzzifier. The fuzzifier converts measured data (crisp values) into fuzzy variables. The knowledge base consists of a database and rule base. The rule base contains the set of fuzzy IF-THEN rules. The database defines the membership functions of the fuzzy sets. The fuzzy inference engine (decision making unit) maps the input space into output space based on the set of fuzzy rules. The defuzzifier converts the processed fuzzy variables back into real values.



a.) FIS



b.) Membership Function

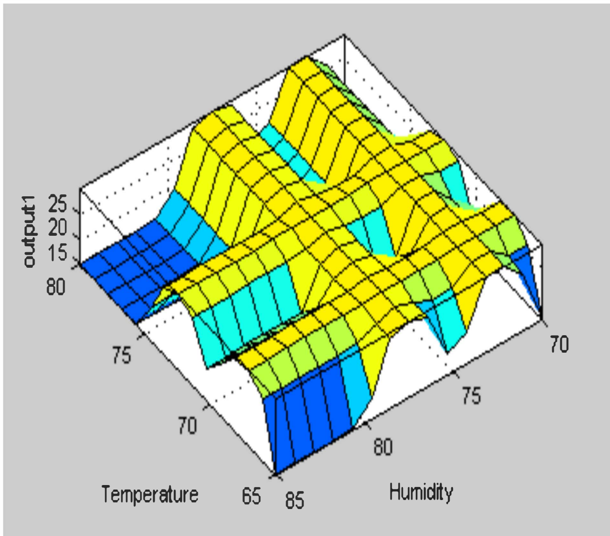


c.) Fuzzy Rule

Figure 9. Fuzzy Simulation of Power/Irrigation Control

The Fuzzy Rule at figure 9-c show the ambient temperature, ambient humidity and soil moisture value that give specific response to the system that can be seen on the output. The fuzzy rule evaluates the data, which is base on the set of membership functions at figure 9-b and that is set of rules given the imperfectness, imprecision, incompleteness and conflicting information coming from the wireless sensor network that install at the crop yeild.

From the output of figure 9-c, It will give precise signal to command center that automatic responds to ON or OFF the control switch for power distribution and solenoid valve for the irrigation control of the system. The result will be the output evaluation of Fuzzy control base on the given input and fuzzy rules. The numerical and graphical presentation of output for power/irrigation control can be seen on Figure 9-d, having parameters of ambient temperature and ambient humidity value.



d.) Fuzzy Surface Output

Figure 9. Fuzzy Simulation of Power/Irrigation Control

IV. CONCLUSION

The Fuzzy Surface Output on figure 9-d, shows the response of the system from the given rules at figure 9-c. FSO from figure 9-d shows the specific results and response from ambient temperature ranging from 65 ^{o}F to 80 ^{o}F and the ambient humidity ranging from 70 ^{o}F to 85 ^{o}F. The output response of irrigation system can be seen changing from 0 to 25 units immediately. It gives immediate response to power control of irrigation that contribute to sudden changes of ambient temperature and ambient humidity of the environment from high to low value. Using fuzzy logic for decision making in power control distribution for the entire system will result to power savings. These Wireless Sensor Network methodologies give promising contribution for advancement of farming industry that results to sustainability of quality fruit and vegetable. The experiment result gives 95 percent accuracy of receiving and sending of data/information and 94 percent of environment data collection that leads to having an energy efficiency for the entire system.

V. ACKNOWLEDGMENT

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