A NOVAL IMPROVED IRRIGATION SYSTEM USING IMAGE PROCESSING AND WIRELESS TECHNOLOGY

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Abstract— A novel irrigation system was implemented to use in agricultural crops. This system uses a raspberry pi with webcam to capture and process digital pictures of the soil close to the root zone of the plant, and estimates optically the relative wet soil(RWS) percentage. The entire system is confined in a chamber and placed it at the root level of the plant under controlled illumination. An algorithm was developed in Python OpenCV to operate directly the computing and communication components such as webcam and ZegBee network. The algorithm runs continuously and activate the all components with pre-defined parameters. Then, the webcam takes an image of the soil through associate window and an RGB to grey conversion is achieved to estimate the quantitative ratio between wet and dry area of the image. After the serial communication is enabled, this ratio is transmitted using Zegbee wireless device to gateway unit. Gateway unit consists of Arduino microcontroller with Zegbee. Arduino processes received information and control the water pump. The system is powered by using rechargeable batteries and charged by using solar panel. The experimental results shows that by the usage of this automatic irrigation system we reduce water consumption and increase yield.

Index Terms—Automation irrigation, Raspberry pi, Python OpenCV, Webcam, Zegbee, wireless sensor network.

I. INTRODUCTION

Irrigation is very important for agriculture to get high yield in semiarid and arid areas. Because the fields in needs of irrigation can contain different plants such as trees, grass and vegetables, each field should be irrigated in a different plan having different period and amount. Of course the person who irrigates the field should be experienced in irrigation methods of the plants to have yield from the plants. In case of wrong irrigation methods, the expected agricultural output cannot be most probably taken.

Raspberry pi have powerful computing and on chip image processing capabilities, connectivity resources and run different applications for multiple purposes. The Raspberry pi microcontroller includes a high performance processor at low-power consumption, running on 1GHz processer, and a memory of variable size, also contains a high-resolution graphics capability. These processers have diverse connectivity options, Local Area Network(LAN), third- or fourth-generation (3G/4G), Bluetooth, and Wi-Fi for Internet and local access. They have a multi-tasking operating system for running first- and third-party Apps, resulting an attractive developing platforms for a specific applications in different domains. Also with additional external sensors the Raspberry pi can enable attractive sensing applications elsewhere, such as environmental monitoring, healthcare, security and transportation.

Raspberry pi been used as external database server, including automated data processing by means of an Algorithm[1]. Other monitoring algorithm was designed for driver fatigue monitoring based on the driver face image and a bio-signal sensor[2]. Another program has been developed to control wheel chair using webcam and raspberry pi based on eye purple tracking[3]. Collaborative Apps predict the scheduled traffic signals and monitor road conditions, using the Raspberry pi with cameras mounted on the car windshields[4]. In some irrigation processes by using co-ordinator node we collect date and transfer that data to Raspberry pi to store and analyse for future use[5].

Mobile devices could be used in important economic sectors -such as agriculture- embracing the value chain for diverse purposes, from the farm logistics to the consumer, employing diverse sensors and information communication technology[6]. Some applications make usage of embedded resources of the device, meanwhile other purposes requires the development of software and hardware. Mobile devices, such as PDAs (personal digital assistant) have used Apps to collect field data for decision making in agricultural production traceability[7]. A mobile phone has been used to send dripper run time scheduling advice via SMS from a water balance system, whereas farmers sent back data about irrigations and rainfalls to update the water balance[8]. The worker uses a GPRS enabled handheld device to capture information on poultry operations collected at a remote chicken farm and transmitted to a back-end server in the main office[9]. A smartphone App runs a web-based whole-farm simulator Simugan, oriented to assist the beef cattle production systems, simulating a scenario with initial values and conditional rules to manage a farm[10].

Other applications for the agriculture sector using mobile devices have been developed; for calculating leaf area with image processing techniques , for estimating the leaf area index (LAI) by two indirect methods , for monitoring farmland air and soil conditions in real time [11], for implementing a Munsell soil-colour sensor for the examination, description, and classification of soils [12], and for detecting pests and plant diseases on leaves by converting the mobile device into a digital microscope [13].

In this work, an improved automated agricultural irrigation system using image processing is described. The system is implemented on a Raspberry pi to estimate optically the water contents of the soil nearby the root of the crop through an OpenCV image processing Algorithem. When the water contents drops at an established figure, the required amount of water is delivered to the crops. This system was linked by a router node as a new wireless sensor unit to the Automated Irrigation System .

II. AUTOMATED IRRIGATION SYSTEM

The irrigation system is based on an embedded webcam interfaced with raspberry pi. The camera with a controlled illumination source takes an image to estimate the amount of water contents of the soil. The dark and light pixels are separated by means of a gray scale analysis, based on the soil wet-dry sectors. A router node is used to forward the contents value to a gateway, which drives a submersible pump to provide automatically the water needs in a crop field. A developed Algorithm uses the processer computing capability and connectivity, including transfer of data to gateway.

The Algorithm wakes-up the system from the standby mode at a given programmable time, activating the processer with a specific set of parameters such as image resolution, screen rotation, and serial communication initialization. The camera is activated to take an RGB picture of the soil. To take the picture of the dark environment in the underground chamber, the region of the soil is lighted by means of built in white ultra-bright LED.

The picture is transformed to a gray scale image and a Relative Wet Soil (RWS) percentage is estimated. The system enables Zegbee module, allowing the transmission of the percentage to a router node.

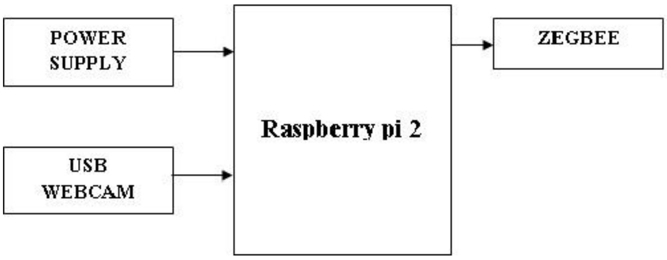

Fig 1. Block Diagram of Co-ordinate Unit

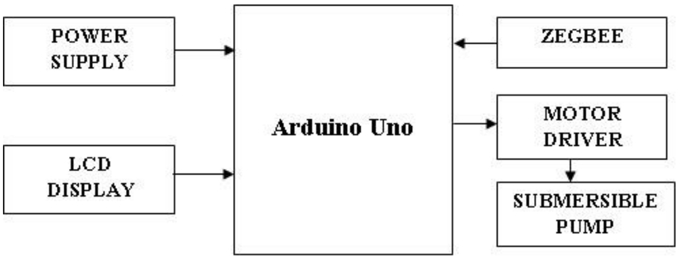

Fig 2. Block Diagram of Gateway Unit

A. Relative Wet Soil Calculation

This system based on the pixel differentiation of a grayscale image produced by diverse water contents in the soil.

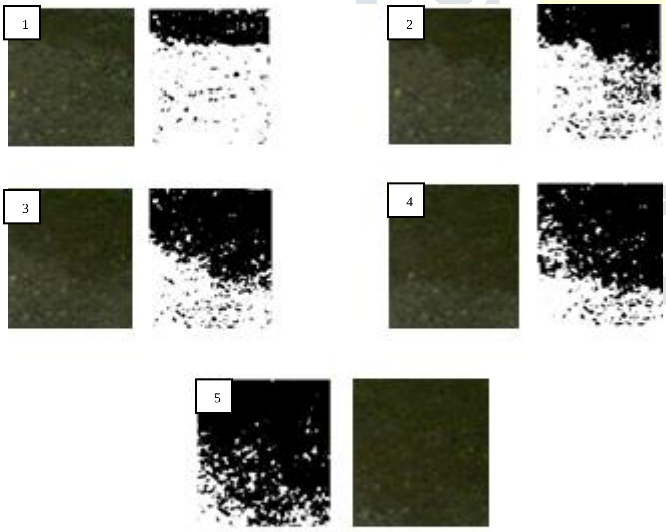

Fig. 3. Images of the soil with different water contents.

To estimate this Relative wet Soil contents a set of images were taken and their pixel differentiation analyzed in the grayscale from 0 to 255, using Python OpenCV library, between an image taken when the soil is at dry condition (Fig. 3.1) and other with completely wet condition means field with water (Fig. 3.5). These two images indicates the limits of the RWS value of the system, which completely depends on the characteristics of the soil like soil type i.e sand, loam, and clay percentages. Other images were acquired at different times of water the system respectively (Fig. 3.2-3.4). As can be seen the number of wet pixels is increased directly proportional to the water contents in the field. Therefore, the RWS is calculated as the number of wet per total pixels.

B. Irrigation Sensor Components

1) Raspberry pi 2

To implement the irrigation system, credit card sized Raspberry pi 2 was selected, which integrates an ARM 11 processor with 1 Gb of RAM and 16 GB of internal memory, runs at 1GHz. It has 4 inbuilt 2.0 USB Ports and Ethernet shield for internet access. For video input HDMI / Composite RCA and for audio input 3.5 mm audio jack interface also available. It runs on Dibean(linx) operating system.

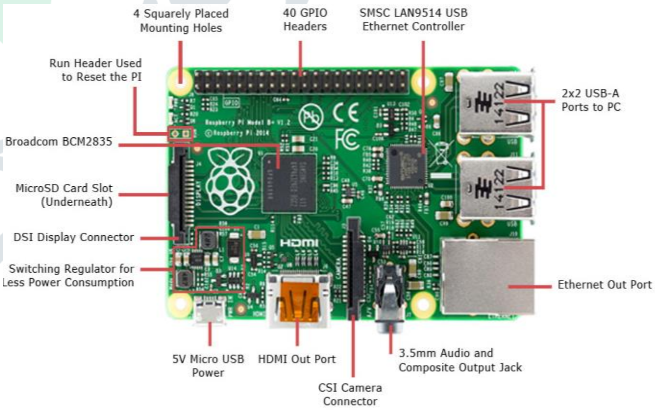

Fig. 4. Raspberry pi 2 Microcontroller

2) Arduino Uno

The Arduino UNO is the microcontroller board based on ATmega328. It has 14 digital input/output pins, 6 analog inputs, 16MHz ceramic resonator, USB connection, a power jack. Arduino consists of a microcontroller and Integrated

Development Environment (IDE). IDE is used to write and upload computer code to the microcontroller. It can be powered by USB cable or power jack of 5v. It contains everything needed to support the microcontroller.

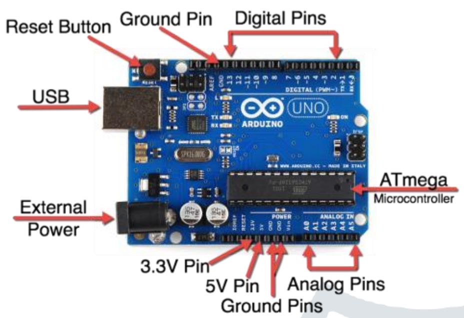

Fig. 5. Arduino Uno Microcontroller

3) Chamber

The Router node is enclosed in the chamber, which is made of rigid PVC plastic with a rectangular cuboid profile of 0.30 x 0.40 x 0.26 m (W x L x H) dimensions and weighing 2 kg. The front chamber face has a window of anti-reflective glass, which dimensions are 0.20 x 0.18 m (L x H) and located at 0.04 m above the bottom edge and 0.03 m from the left edge.

4) Wireless communication Network

The wireless router node was developed by means of an XBee radiomodem (Digi International, Eden Prairie, MN), linked with the serial port of raspberry pi and an XBee-PRO S2 radiomodem to link the node to the gateway. Both radiomodems are communicated to transfer a data that includes the router node identifier, the RWS percentage. The energy is provided with a similar power supply employed for the illumination circuit.

C. Irrigation Algorithm

The Algorithm was programmed by means of the python 2.7. Which allows the development of multiplatform applications. It imports the OpenCV library to perform image processing tasks. Initially, the algorithm requests for a user defined time to start a periodically process. This loop, customizes the camera to a specific resolution, enables Xbee network to send data. After, the algorithm takes a RGB image and is converted to grayscale, a sector of this image is selected to eliminate the edges and is employed to calculate the RWS percentage and transmitted to the microcontroller-based gateway via the router node. The smartphone goes into sleep-mode. When the user-defined-time is elapsed, the loop starts again.

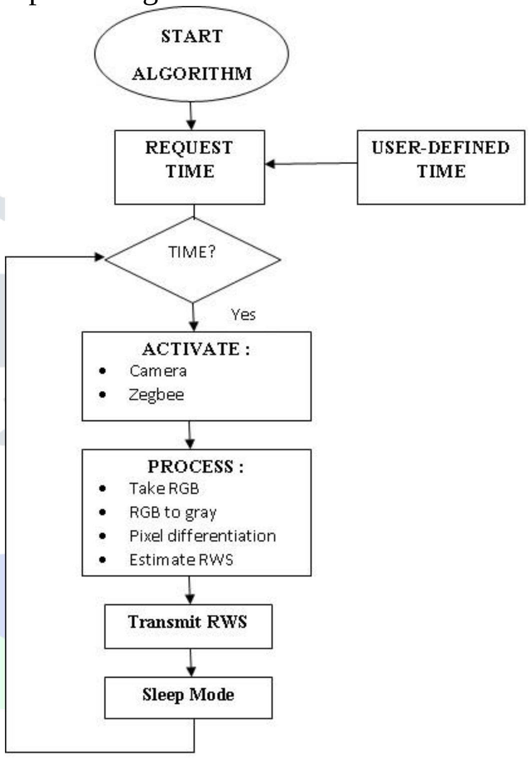

Fig. 6. Automated irrigation Algorithm

The RWS is estimated according to:

1) RGB to gray

The RGB components R(i, j), G(i, j), and B(i, j), where i and j denote the spatial coordinates of the pixels, are converted to a gray scale matrix I(i, j), based on python rgb to gray conversion equitation .

$$I(i, j) = 0.2989R(i, j) + 0.5870G(i, j) + 0.1140B(i, j)$$

2) Pixel differentiation

The gray image I(i, j) is subtracted from a light field matrix L(i, j), to enhance the image. The dark and light pixels that correspond to the wet and dry ones is differentiated, comparing them to an established ε limit:

$$H(i,j) = \begin{cases} 1 & \text{if } [I(i,j) - L(i,j)] < \varepsilon \\ 0 & \text{if } [I(i,j) - L(i,j)] \geq \varepsilon \end{cases}$$

$$k = \sum_{i-1}^{n} \sum_{j-1}^{m} H(i,j)$$

where k is the number of wet pixels, meanwhile n and m represents the size of the digital image.

3) RWS

The percentage of the ratio between wet (k) and total (n × m) pixels represent the relative wet soil value, given by:

$$RWS(\%) = 100 \times (k / (n \times m))$$

This percentage is truncated at integer values, so the resolution is one unit.

III. OPERATION AND EXPEIMENTAL RESULTS

To test the Proposed novel irrigation system, we take some sort of soils and by adding water we observe the RWS value. The value of light field matrix is selected based on the type of soil. The combination of raspberry pi and USB camera is responsible for capturing image of the soil at root zone. Depends on the moisture content of soil processer calculate the RWS value and transmit wirelessly using Zegbee. At the gateway unit Arduino uno receives RWS value using zegbee. If the received value is greater than 70% it automatically turns on the submersible pump. If the value below 30% it automatically turn off the pump. In order t drive both Coordinator node and gateway unit we use the rechargeable battery which is charged by using Solar panel. The snapshots of the proposed system is shown below.

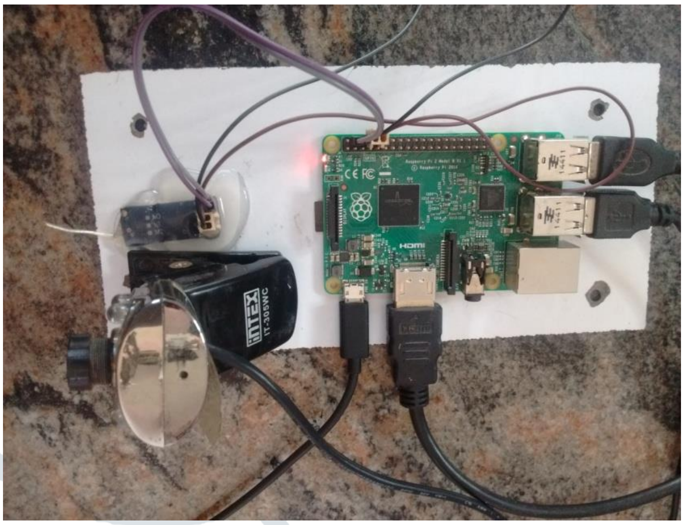

Fig. 7. Coordinator Unit with Zegbee

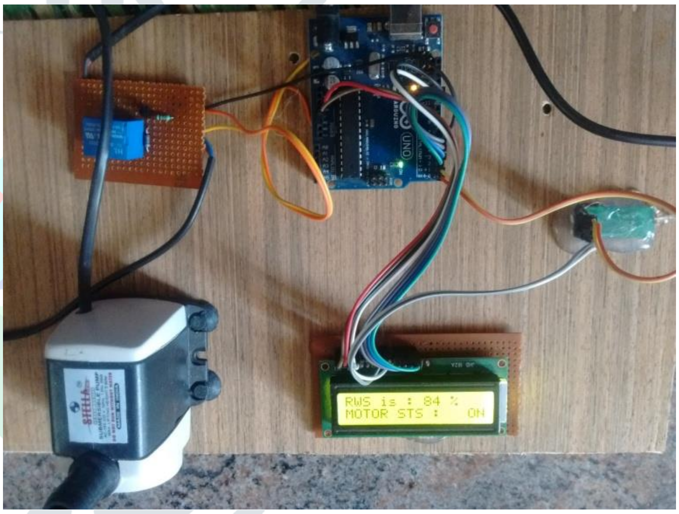

Fig. 8. Gateway Unit.

IV. CONCLUSION

The developed novel automated irrigation system complied with the conceived concept of an optically triggered automated irrigation using a soil imaging process. Due to rapid growth of raspberry pi at affordable prices, this system represented a simple and practical implementation. This system has an inherent advantage over other kind of soil moisture sensors for irrigation purposes. The outcome of others depend of soil characteristics like: density, compaction, gravimetric or mixture of their components among others. The irrigation sensor is of non-contact type, requiring only an in situ calibration to acquire the dynamic range for any soil type. This is performed using a dry soil image and another water saturated. This procedure may represent a disadvantage respect to other kind of sensors. The system is watering to the crop uniform by analyzing the soil parameters, it will help to reduce the fresh water consumption. The ZigBee protocol is used here for wireless communication it will create network easily and combination of Arduino, Xbee and sensor create a low power inexpensive sensor node.

V. FUTURE ENHANCEMENT

The system can be used creating networks for large fields or for uneven cultivation terrains, in such a way that several places have to be monitored for different RWS values. Also if needed there are other communication capabilities such as Bluetooth or directly through a SIM card via SMS linked directly to a URL site or other raspberry pi, integrating several versatile possible applications. If a gateway is not required, the irrigation sensor can be used alone to trigger remotely an irrigation pump. To increase the sampling points in the field and by means of the XBee-PRO S2 radio modem, the range can be extended up to 1.6 km.

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