IMPLEMENTATION OF IoT (INTERNET OF THINGS) AND IMAGE PROCESSING IN SMART AGRICULTURE

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***Abstract*—Internet of Things and Image processing have been so far been applied for various applications independently. Their individual application in the field of agriculture exists and has achieved certain degree of success, however the combination of both these technology so far is non-existent. This paper describes an approach to combine IoT and image processing in order to determine the environmental factor or man-made factor (pesticides/fertilizers) which is specifically hindering the growth of the plant. Using an IoT sensing network which takes the readings of the crucial environmental factors and the image of the leaf lattice, it is processed under MATLAB software by the help of histogram analysis to arrive at conclusive results.**

***Keywords*—Internet of Things (IoT), Image Processing, Sensing network, MATLAB**

I. INTRODUCTION

India is an agricultural country. More than seventy per cent of the population depends on agriculture. Thus, our economy is majorly depended on agriculture. Thus development in this field will highly contribute to the economic welfare. Technology is playing its role in bringing about change and progress in many sectors. Agriculture is one such sector, which when collaborated with technology such as Internet of Things combined with image processing can result into cheap yet effective methods of agriculture, which in turn will give rise to higher quality produce. This approach to agriculture still stays uncharted and hence it's high time that we take a step in this direction.

The Internet of Things is the network of physical objects—devices, vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity—that enables these objects to collect and exchange data. The Internet of Things has been defined in Recommendation ITU-T Y.2060 (06/2012) as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies. Building an IoT application requires the right selection and combination of sensors, networks and communication modules. The above setup is then collaborated with concepts of image processing, cloud computing, etc. Research conducted in September 2014 on early IoT adopters, suggests that the majority of the companies that have adopted IoT are already seeing some measurable benefits. Respondents said that they have deployed or plan to use IoT in many areas, including asset tracking, security, fleet management, field force management, energy data management, and condition-based monitoring. IoT has wide applications in the fields of transportation, lifestyle, building, agriculture, factory, health care and many more. It is often described as a network of networks. Due to this, it can perform various tasks efficiently and accurately.

Image processing is processing of images using mathematical operations by using any form of signal processing for which the input is an image, a series of images, or a video, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics of parameters related to the image. It usually refers to digital image.

Digital image processing makes use of various computer algorithms to perform image processing on digital images. It is widely used for classification (identifies to which class does a newly found observation belong), pattern recognition (recognize known and discover unknown patterns), feature extraction (initial information which is used to make further derivations), multi-scale signal analysis (signal processing) and projection (three dimensional object is converted into a planar surface). The block diagram of IoT is as shown in figure 1.

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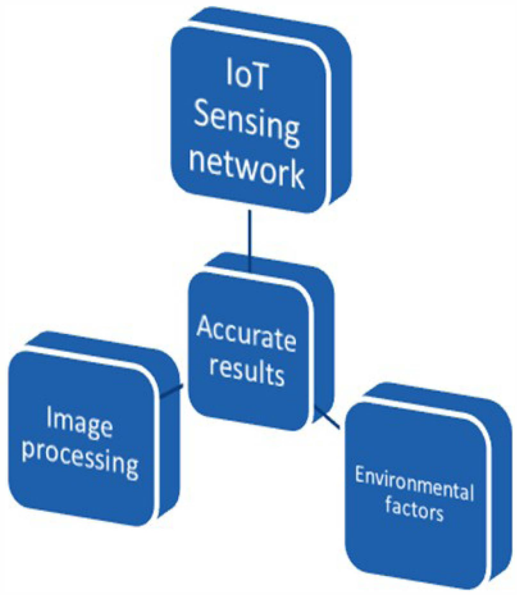


Fig 1. Block diagram of IoT

As discussed earlier, IoT and Image processing can be used in the agricultural domain to have higher quality produce and thus reduce crop failure. We aim at reducing crop failure by letting the farmers know what environmental conditions such as temperature, humidity, light, soil moisture is most suitable for the crop and what are the effects of the fertilizer used. This is done by constantly monitoring the crops using an IoT based circuit that includes Arduino, sensors for the different environmental factors and a camera that will capture images of the crops at regular intervals. The images captured will be processed to recognize the various morphological changes occurring due to different environmental factors. If there is any change that corresponds to the deterioration in the plants growth, the farmer is immediately informed. Early diagnosis will thus help in taking the necessary actions to increase the produce and reduce failure of crops.

The remaining part of the paper is organized into four sections. Section two deals with the literature survey. Section three explains the proposed method. Section four gives the results and discussion and finally section five deals with conclusion.

II. LITERATURE SURVEY

Authors in [1] have used color and pattern analysis to identify multiple deficiencies in paddy leaf images. Authors in [2] have proposed a system framework which combines cloud computing and unified internet of things. In [3] authors have suggested a methodology to regulate water in agricultural fields. In [4] authors promote the fast development of agricultural modernization and help to realize smart solution for agriculture and efficiently solve the issues related to farmers. In [5] authors have provided the use of Internet of things in agriculture. Authors in [6] have discussed various application of image processing in agriculture. In [7] authors have proposed a method to visualize and trace agricultural products in supply chain. Authors in [8] focus on the hardware architecture, network architecture and software process control of the precision irrigation system. In [9] authors have focused on the study on the application of cloud computing and the internet of things in agriculture and forestry.

III. METHODOLOGIES

The basic idea is to combine the concepts of Internet of things along with the techniques of image processing to arrive at accurate results. It is known that temperature, humidity, soil moisture and light intensity lead to subtle to drastic changes in the health of the plant. The morphological changes that a plant undergoes is captured and analyzed on the MATLAB software using the algorithms to arrive at the result. The whole process of capturing the image along with the requisite environmental factors are done at once using the IoT sensing network and the data is fed onto the SD Card for further analysis.

The specific components that are used in the IoT sensing network are Soil Moisture sensor, DHT11 (Temperature and Humidity sensor), Serial JPEG camera module (To capture image at regular intervals) and SD Card Shield using an 8 GB SD card. The set of sensors and the image processing camera assembled on an Arduino UNO. The program is written in the Arduino language which first activates the sensors namely the soil moisture and the DHT11 sensor and subsequently captures a snapshot of the plant and stores in the SD Card.

This brings into the attention the type of the plant that is used in the experimental analysis. For the sake of the experiment, it needed such a plant that showed moderate to drastic changes on subtle changes in the vicinity. And at the same needed low maintenance. Keeping these things in mind, owing to the rationale behind the selection of the right plant, Philodendron (an indoor ornamental plant) was selected. It shows moderate to drastic morphological changes in short span of time enough to be processed by the MATLAB algorithms.

Once the test image is taken by the camera module, it tested and run against a set of pre-defined database of images already taken keeping the environmental constraints as well as general artificial crop catalyst in mind namely N, P and K.

The algorithm thus analyses the given image and arrives at the conclusion which refers to the specific problem that affected the given plant. The figure 2 shows flow diagram that illustrates the whole process.

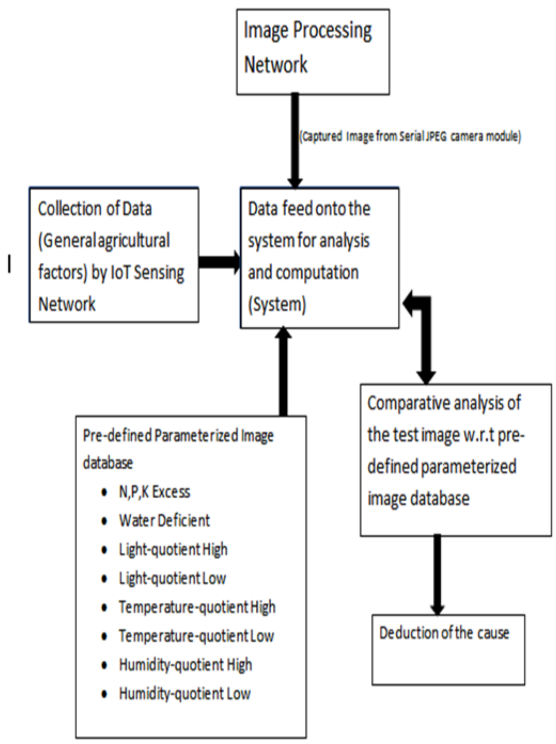


Fig 2. Flow diagram of the process

A.Algorithm for DHT11 (Temperature and Humidity)

Step 1: Initialise the sensor to send data at 9600 baud rate

Step 2: Start reading humidity and temperature values from the assigned analog pin

Step 3: Print to in ^C and Humidity in % on the serial monitor

Step 4: Continue to read data at a delay of 2000ms

Step 5: De-initialise the sensor and terminate

B. Algorithm for Soil Moisture sensor

Step 1: Initialise the sensor to send data at 9600 baud rate

Step 2: Start reading moisture_level value from the assigned analog pin.

Step 3: if moisture_level >900

Print "Low"

Else if moisture_level<900 && moisture_level>500

Print "Medium"

Else

Print "High"

Step 4: Continue to read data at a delay of 2000ms

Step 5: De-initialise the sensor and terminate

C. Algorithm for Image Capturing using serial JPEG camera module and storing it on the SD Card

For this the requisite header files are included namely softserial.h and SDFat.h. The buffer of the SD Card is cleared and initialized. The chip select pin is assigned on the Arduino. The camera is initialized for transferring the stream of bytes. The function SendCmdpic() is run which takes pictures at a delay of 300ms. Subsequently each picture is titled serially. SendReadDataCmd() command is run to get the picture from the camera buffer and stored onto the file. The process of reading and writing is dined at adequate delay so as to not lose intermediate buffer.

The above algorithms are utilized to capture image for morphological analysis and at the same time utilized to read the present weather conditions that are currently influencing the plant under normal conditions without any human intervention. The data so collected is fed onto the system for computational purposes to narrow the specific factors which have led to the plant's deteriorated state. The circuit diagram to achieve the proposed method is as shown in fig 3.

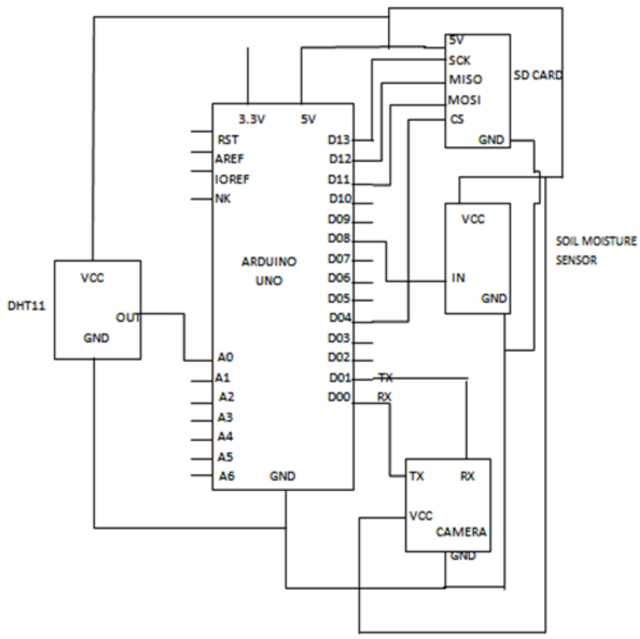


Fig 3. Circuit diagram

Before proceeding with the test image to find out the specific environment factor and mineral factor that has affected the plant's present, a database is prepared for the histogram analysis. The images are converted to a monotone to obtain accurate results. Four sets of the same plant are taken for the same plant; Philodendron Ceylon in this case, is subjected to specific variations of the environment. The healthy conditions for this plant are moist conditions with low to moderate sunlight requirement for its metabolic activities to function normally. Set 1of plant is kept under normal healthy conditions. Set 2 of the plant is kept under extreme sunlight conditions with moist conditions being maintained. Set 3 is kept under low to moderate sunlight with little to no water being given to it. Set 4 is treated with excess of N, P, and K fertilizer under normal environmental conditions. For each of these sets, visible morphological differences were seen. These visible morphological differences give way for histogram analysis for each plant. Each histogram plot for each set will be variably different. A sample healthy plant and its histogram is as shown in figure 4.

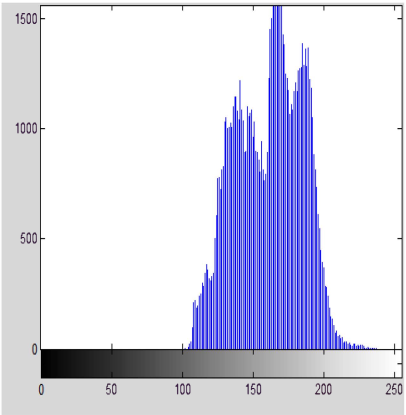


Fig 4. Set 1(Healthy) Histogram for Set 1

Analysis

The deterministic factor for this is the non-variation of the color over a specified range. Here, it is clearly visible for the range 150 to 175, the numbers of corresponding pixels are high i.e. above 1500 pixels (image sixe: 640 x 484). Also it is important to note that for range little less than 150 and little above 175, the number of pixels are also high, thus exhibiting, the color variation is low, and the number of pixels corresponding to one particular value on the scale, will have a peak and the number of pixels in the neighboring region will also be high. Another important observation is the there are no pixels in the range of 1 to 100(depicting dark tone) thus conclusively proving that there are no dark spots in the leaf and hence is healthy.

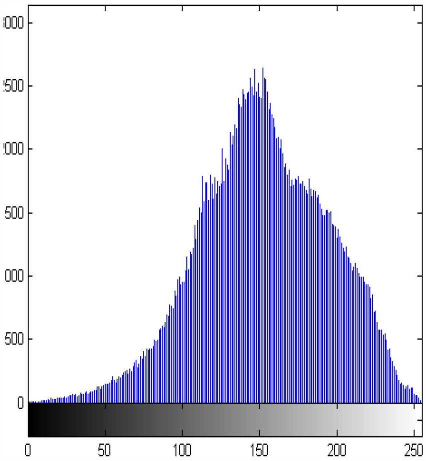


Fig 5. Set 2(Dry) Histogram for Set 2

Analysis

The most critical observation is to notice the range from 0 to 50. Since in this the black spots have just started to emerge on the lattice. This means that there will be pixels that must correspond to the range 0 to 50 (image Size: 640 x480). The number of such pixels will be less vis-à-vis other sets (except Healthy set) but the mere presence of pixels in this range is a significant observation that is clearly distinguishable from other histograms. Speaking in terms of counter-measures, on constant observation, if the number of pixels keeps on rising in the range of 0 to 50, it must trigger procedures to counter this specific cause which is dryness as shown in figure 5.

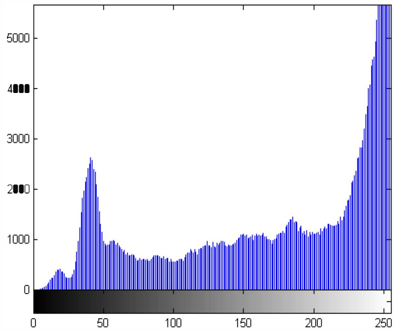
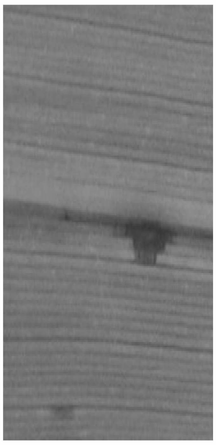


Fig 6. Set 3(Excess Heat) Histogram for Set 3

Analysis

The most important observation is to notice the vast variation in the number of pixels in the range of 200 to 250 (above 5000) and vis-à-vis to the number of pixels in the range 0 to 50 (around 2500). This implies in the image of excess heat, there will always be a large variation in principle. Also there must be a region in the histogram where for extreme dark tones, a peak will be visible and a peak will also be there for extreme light tone. The peak for dark tone represents the dark spot on the lattice of the leaf clearly visible at right end of the leaf. For all other excess heat leafs the pattern looks as shown in figure 6.



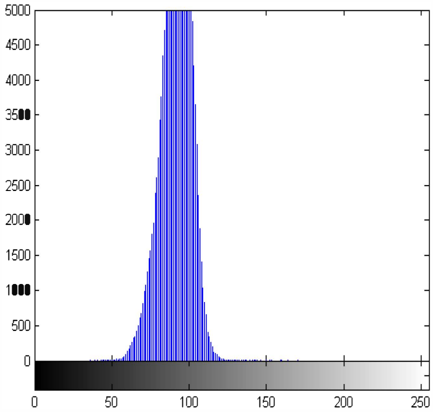


Fig 7. Set 4(NPK Excess) Histogram for Set 4

Analysis

The point of observation is dark spot that appear at the certain points on the lattice, which is visible in the histogram also. For the point around 80, the numbers of pixels are more than 5000 thus depicting the dark spot which has arisen due to NPK Excess criterion on the lattice at some point. The dark spots are unique to this set and the histogram so generated clearly depicts the analytical capabilities of image processing. The N, P, K excess leaf and histogram is as shown in the figure 7.

The Histograms for each set is different as the analysis clearly shows, thus allowing for the test images to be put under observation to determine the exact deficiency that hinders the plant.

IV. RESULTS AND DISCUSSIONS

The aim of the experiment from its inception was to show how image processing techniques can be used to assess and analyze the health of the plant. Including the concepts of Internet of Things makes the whole process is automated and more consolidated data is obtained using the sensing network. Using the IoT network, we assess the exact variations the plant undergoes during the course of time allowing to pin-point the specific deficiencies that the plant faces in terms of mineral requirement or environmental adjustments. The images are obtainable from the SD Card that has been installed on the IoT Sensing network and fed onto the system. By corroborating the histograms for all the sets, it can be analyzed to conclude the deficiency that is currently affecting the plant. Therefore, using the IoT Sensing network that contains the exact temperature, soil moisture, humidity data, the information is collaborated to validate the findings by the image processing results so obtained. Thus, allowing for validation of the image processing technique used in the setup.

The pattern for each set will be similar in nature. The characteristics of each plot will be similar that allows to analyze and conclude the specific factor be it environmental or fertilizer affecting it. The images are captured by the IoT sensing network and at the same time the data is noted down. Some sample results of healthy specimen are as shown in figure 8.

Test Image 1:

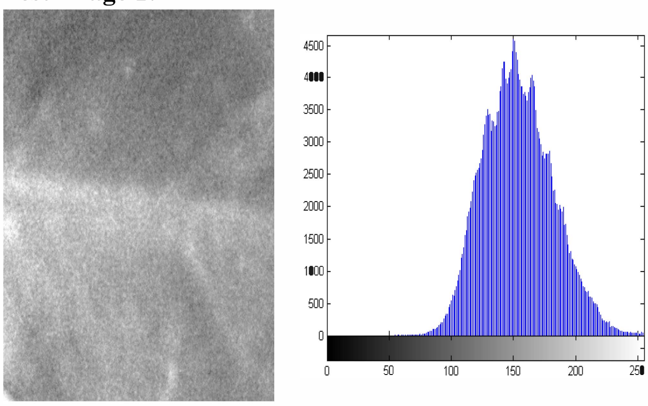


Fig 8. Healthy specimen

Temperature from DHT11 Sensor: 26*C
Humidity from DHT11 Sensor: 25%
Soil Moisture Level from Soil Moisture Sensor: Medium

Histogram Analysis

As it can be seen, that for this test image there are no pixels in the range 0 to 80, thus establishing the fact that there are no dark regions in the lattice. Also for the range 150 to 180, there is little variation in the number of pixels (above to 4500 to around 3500) thus proving that the maximum pixels are of the same shade or tone. Hence the test image is healthy. The findings is compounded by the sensor readings also.

Test Image 2:

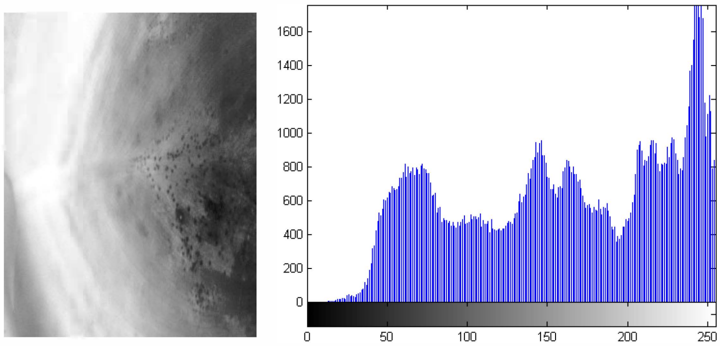


Fig 9. Excess heat specimen

Temperature from DHT11 Sensor: 38*C
Humidity reading from DHT11 Sensor: 25%
Soil Moisture Level from Soil Moisture Sensor: Medium.

Histogram Analysis

The similarity to the excess heat database histogram is clearly evident. For the range 280 to 200, the number of pixels suddenly shoots up, verifying the extreme light regions that are present in the specimen. Also, for the range 50 to 100, there exist a fair number of pixels describing the presence of the dark regions on the lattice. The slight peak in the region of 50 to 100 is the deciding factor that pin-points the deficiency and puts the test image under the Excess Heat Category. The Sensor values from the IoT network also support the conclusion drawn from the image processing analysis. Figure 9 shows result of excess heat specimen

V. CONCLUSION AND FUTURE WORK

It can be seen how Internet Of Things and Image Processing can be combined and implanted in the field of agriculture and how exactly they need to be combined in order to get satisfactory results. Here some level of automation is achieved in terms of capturing images in regular intervals. Also the status of the environment is regularly checked and updated. This gives rise to the possibility of constant monitoring of the fields and the environmental factors. The IoT sensing network so established can easily be mounted on a rover or even a drone to monitor and collect data of the field on a regular basis. This will immensely help the farmers as they cannot be on their field 24*7. The information so collected can be communicated to the farmers using CDMA/GSM protocol. Given the environmental factors under observation, remedial measures can be taken. The rovers can have the specific amount of pesticides, fertilizers on board. The levels of the minerals in it the soil is computed using the techniques so described. Based on these readings, the requisite amount of minerals can be put on the soil.

An arena of information technology that can be combined with this system i.e. Cloud computing. The database so collected and variation in the morphological features of the plant can be extrapolated to corroborate a one-to-one relation between them. The cloud database so created can be used to formulate the specific remedial measures that should be taken for them. For each condition and variation, the altering levels of the minerals in the soil combined with the morphological alterations, the remedial measures can be formed as the IoT opens such possibilities. As IoT explores the interconnecting of devices, cloud computing concepts can be established with them for a complete consolidated system.

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