International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8, Issue-1, May 2019

Electronic Monitoring and Disease Diagnosis of Oryza Sativa Crops through an IoT Enabled Embedded System

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Abstract**: *Rice is one of the most important crops in human history, and is a staple diet of a majority of the human population at any given point in time. It is therefore of utmost importance to maximize the yield of every harvest of rice for a multitude of reasons, from increasing profit margins to reducing world hunger. With the current advancements in technology it is possible to monitor the growth and progress of a crop to a level not feasible before. This work is an attempt to create a fully self-sufficient, IOT enabled embedded system to automate the processes related to rice crop farming. The environmental condition parameters like water, humidity, soil moisture, spread of diseases can be conveyed to a farmer. The system is based on intelligent sensing, thereby reducing the power consumption and the need to frequently replace sensors. The data recorded enables the farmer to make informed decisions for crop maintenance from a remote location at a low cost.***

Index Terms**: *Raspberry Pi, Oryza Sativa, Magnaporthegrisea, Rice blast, OpenCV***

I. INTRODUCTION

Agriculture contributes greatly to the Indian Economy. Indian agriculture sector's contribution is to the tune of 18 % of India's gross domestic product (GDP) and around 50 per cent of the country's workforce is a direct beneficiary of it. India produces a voluminous amount of pulses, rice, wheat, spices and spice products. Th5e country has come a long way in harnessing the business potential of sectors such as dairy, meat, poultry, fisheries and food grains etc. India is the second largest producer of vegetables and fruits in the world. According to the data provided by Indian Government agencies, the total production of food grains during the year 2013-2014 is 264 million tons which is more than the 257million tons produced for the year 2012-2013. The objective of this work is to develop a low cost user-friendly electronic embedded system to automate the process of crop monitoring – a variety of sensors are used to collect physical parameter data in the vicinity of the system to draw conclusions about action required for the crop, such as temperature, soil moisture, humidity etc. An image processing component is also included and adds the functionality of crop disease detection and diagnosis for up to four diseases. The crop under focus was rice, or Oryza Sativa. This crop was chosen in accordance to its status as the staple food of a majority of the population of Southeast Asia, and arguably the world. Also as the crop being grown in most third world and developing countries, it is usually the case that the methods of growth and cultivation are not very scientific, with "old knowledge" being a prevalent source of information to farmers, which are not in line with current standard practices and scientific techniques based on real time data [1-2].

A. Need for Crop Monitoring

Crops are quite essential to human beings. They are a source of food, they improve food supply and increased food supply enables populations to grow and sustain. With the population increasing at an exponential rate and lifestyles of people changing at a very fast pace, the demand for food will only increase. Hence this puts an enormous pressure on the land and the farmers to cultivate to the requirement and to meet the demand, effective crop management is very much required [3-4]. Crops have strict temperature, water and pesticide requirements and a substantial deviation from the prescribed values will lead to crop loss and will affect the yield of the produce [5-6]. Crops entail heavy investment on the farmer's part and the sale of crops is the only source of revenue for farmers. In case crops get damaged due to improper monitoring it will lead to loss in revenue for farmers and the return of investment will be very less. Hence, an IoT enabled, intelligent sensing embedded system based solution has been attempted in this work [7-8].

B. Selection of Crop

Of all the crops that were analyzed, Rice was found to be the crop which attracted a lot of attention. Since the dawn of the civilization, Rice has shaped the culture, diets and economic of thousands of people. Taking note of its importance, the United Nation had given the year 2004 the designation of the international year of rice. Rice is valued as a nutritional food item which provides instant energy as its most important component is carbohydrate (starch). On the other hand, rice is deficient in substances containing nitrogen with the average composition of these substances being only 8per cent and fat content or lipids only 1% and due to this reason, it is considered as a complete food for eating.

Revised Manuscript Received on 30 May 2019.

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Rice flour has high starch content and is used for preparing various food ingredients. It is also used in some instances by brewers to make alcoholic malt. Similarly, rice straw when mixed with other materials produces porcelain, glass and pottery which are very useful to mankind. Rice is also used in the manufacturing of paper pulp and in the bedding of livestock [9-10].

II. METHODOLOGY

This work aims to measure, analyze and optimize parameters which affect the growth of the crop like temperature, humidity, water level, soil moisture. The sensors required for measuring values are connected to the Raspberry Pi and a camera is also used for acquiring the images of the field. The block diagram of the entire system is shown in Figure 1.

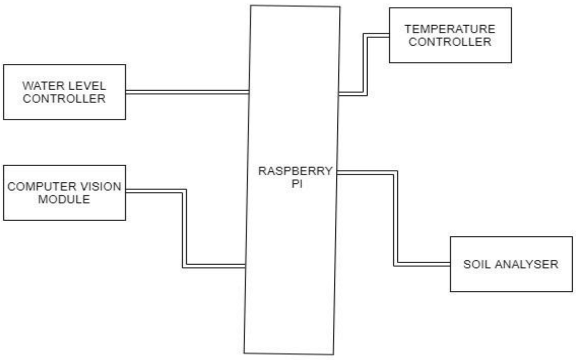


Fig 1: Flowchart of the entire embedded set-up

A. Temperature Controller

Figure 2 shows the operation of the temperature controller. This module checks if the temperature is optimum for crop cultivation and intimates the user in case of abnormalities.

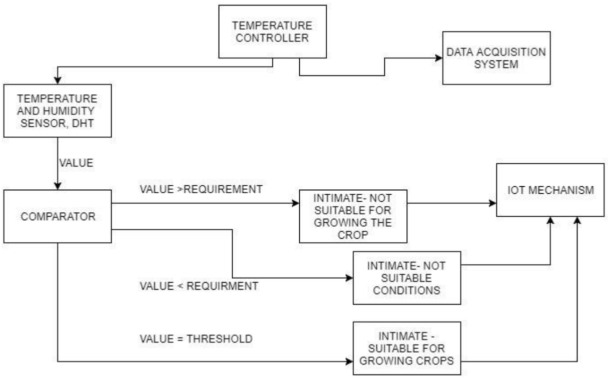


Fig 2: Control flow of temperature controller

B. Water Level Controller

The water level controller is used to control the water level of the paddy field. A DC motor based water sprinkler and drain system is used to control the water level. Figure 3 shows the working of the controller unit.

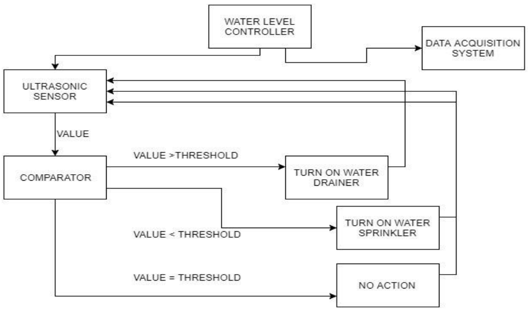


Fig 3: Flow diagram of water level controller

C. Soil Moisture Controller

The soil moisture controller is used for analyzing the moisture content of the soil. The results of the sensor reading operation are sent to the cloud through the aforementioned IoT mechanism [11]. In case the measured values are not in line with the thresholds, counter measures are deployed Figure 4 shows the flowchart of soil analyzer operation.

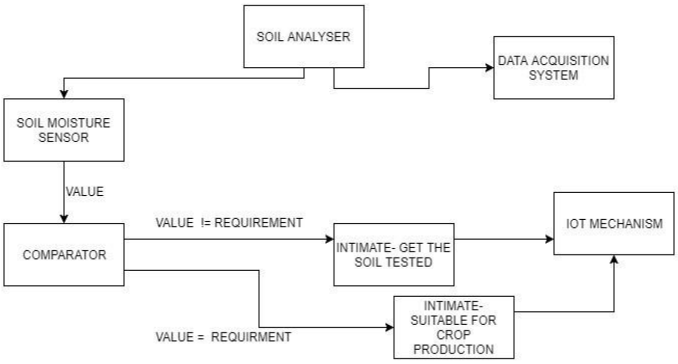


Fig 4: Flowchart of Soil moisture controller operation

D. Computer Vision Module

The computer vision module detects the presence of diseases on crops and intimates the user so that corrective action can be taken. An image is acquired from a USB camera connected to the base Raspberry Pi and stores it on the SD card in an appropriate work directory. A python program in the same directory is run to implement the OpenCV detection of the disease in the leaf, if any. The diseases looked for are sheath rot, rice blast and brown spots. The treatment corresponding to each disease is intimated to the user. Figure 5 shows the working of the computer vision module.

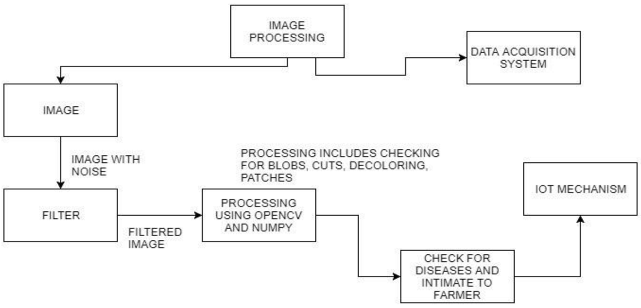


Fig 5: Computer vision module flowchart

E. Sensor Specifications

The specifications of the sensors used in this work are presented in table 1 and 2.

Table 1. DHT 11 Specifications

METRIC	RELATIVE HUMIDITY	TEMPERATURE
Resolution	16 BIT	16 BIT
Repeatability	± 1%RH	± 0.2^{O} C
Accuracy	AT 25^{O} C ± 5% RH	± 2^{O} C
Sensitivity	1%RH	1 ^{O}C

Table 2. HC- SR04 Specifications

Resolution	1 cm
Maximal range	400 cm
Minimal range	3 cm
Sampling period	50 ms
Accuracy	Upto 3mm
Precision	0.1-0.5 cm

F. Cloud – Node Communication Protocol

The sensors attached to the nodes are activated and the values are recorded in the cloud. The cloud platform being used in this work is ThingSpeak. The measured values are compared with threshold values, those being the optimum values required for generating high yield from the farm. Based on the deviation from the threshold values, the intelligent sensing algorithm shifts the state of the system to either the warning state or the normal state. While in the warning state, the sensors are activated in cycles of 15 minutes, the values measured are constantly compared with the threshold values. The intimation protocols are then activated. The intimation protocols used in this work are e-mail, wherein a mail is sent to the user’s Gmail account, and an SMS system, wherein an SMS will be sent to the users registered mobile number so that the user can take necessary action. At the same time counter measures will also be deployed, namely, the water pump will be turned on incase the field is deficient in water and moisture. The counter measures are deployed until the problem is solved Once that happens, the system goes back to the normal state wherein the sensors are activated and values are measured in cycles of 1hr [12]. The intelligent sensing algorithm engenders power saving and the same has been discussed later in the paper. The computer vision module captures the images of the crop during the various stages of the germination process and checks for decoloring of leaves, cuts, bloats, weeds and insects. The module then analyses the crop and suggests solutions to mitigate the effects of the same.

III. RESULTS AND DISCUSSION

The results obtained after the successful implementation of the prototype have been discussed in the subsequent sections. The working of all the modules of the prototype has been clearly explained.

A. Hardware Implementation

The prototype model is shown in Figure 6. The placement and arrangement of the sensors can be observed in figure 6. Figures 7-10 are the results obtained from the sensors which have been used in the prototype, the data obtained from the same which have been uploaded to the ThingSpeak cloud platform.

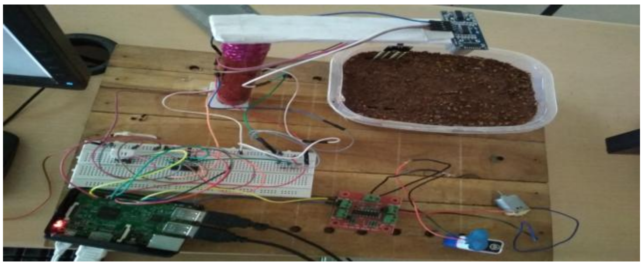


Fig 6: Complete Hardware prototype

B. Observations from Humidity Sensor

This sensor records the humidity of the areas in the near vicinity of the sensor. Figure 7 shows the values recorded by the humidity sensor, these values have been uploaded in the cloud. It can be seen that humidity has peaked at some time before 14.20 PM on the day of recording.

Fig 7: Humidity sensor observation

C. Observations from Temperature Sensor

The DHT 22 sensor has been used to record the temperature of the field. Figure 8 shows the values recorded by the temperature sensor on a particular day. It is seen that the temperature has reached a local minimum at about 14.15 PM on the day of recording.

Fig 8: Temperature sensor observation

D. Observations from Water Level Sensor

This sensor module records the level of water in the paddy field. Figure 9 shows the level of water in the paddy field at different times of the day.

Fig 9: Water level sensor observation

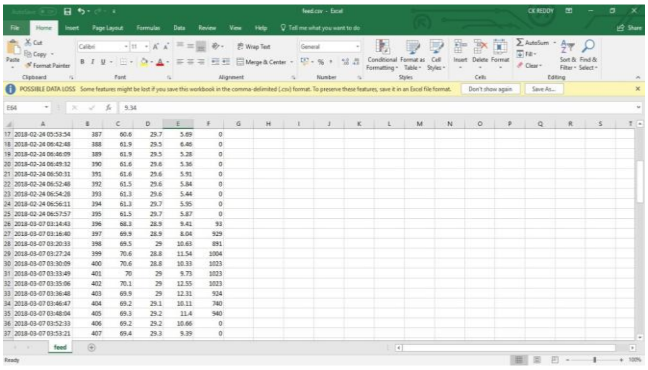
E. Observations from Soil Moisture Sensor

The moisture content of the soil is measured by the soil sensor. Figure 10 is a graph of the moisture levels of the field with respect to time. Frequent changes are seen due to the fact that moisture is a relatively more volatile parameter as compared to humidity and temperature.

Fig 10: Soil Moisture sensor observation

F. Data Collection and Storage

Data is exported in the form of an excel sheet with precise values along with the time and date of data entry as shown in Figure 11. This data can be used to prepare graphs and analyze the data to optimize resources.



POSSIBLE DATA LOSS Some features might be lost if you save this workbook in the comma-delimited (.csv) format. To preserve these features, save it in an Excel file format.

E64 9.34

	A	B	C	D	E	F
17	2018-02-24 05:53:54	387	60.6	29.7	5.69	0
18	2018-02-24 06:42:48	388	61.9	29.5	6.46	0
19	2018-02-24 06:46:09	389	61.9	29.5	5.28	0
20	2018-02-24 06:49:32	390	61.6	29.6	5.36	0
21	2018-02-24 06:50:31	391	61.6	29.6	5.91	0
22	2018-02-24 06:52:48	392	61.5	29.6	5.84	0
23	2018-02-24 06:54:28	393	61.3	29.6	5.44	0
24	2018-02-24 06:56:11	394	61.3	29.7	5.95	0
25	2018-02-24 06:57:57	395	61.5	29.7	5.87	0
26	2018-03-07 03:14:43	396	68.3	28.9	9.41	93
27	2018-03-07 03:16:40	397	69.9	28.9	8.04	929
28	2018-03-07 03:20:33	398	69.5	29	10.63	891
29	2018-03-07 03:27:24	399	70.6	28.8	11.54	1004
30	2018-03-07 03:30:09	400	70.6	28.8	10.33	1023
31	2018-03-07 03:33:49	401	70	29	9.73	1023
32	2018-03-07 03:35:06	402	70.1	29	12.55	1023
33	2018-03-07 03:36:48	403	69.9	29	12.31	924
34	2018-03-07 03:46:47	404	69.2	29.1	10.11	740
35	2018-03-07 03:48:04	405	69.3	29.2	11.4	940
36	2018-03-07 03:52:33	406	69.2	29.2	10.66	0
37	2018-03-07 03:53:21	407	69.4	29.3	9.39	0

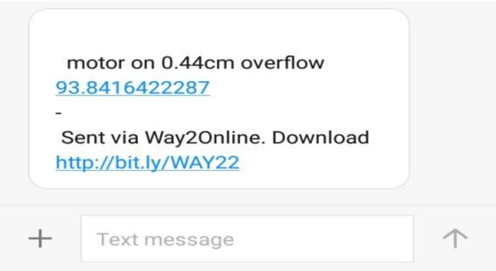
Fig 11: .csv (excel) file generated by logging of sensor readings on the cloud

G. Water Sprinkler and Water Drain

When the soil moisture level dips or is greater than the acceptable value, the water sprinkler or the water drain is switched on respectively. Both these modules are controlled by the microprocessor. A DC motor is used for this operation. The data pertaining to the motor function is sent to the user.

H. Intimation Techniques

Figures 12 shows the user receiving intimation via SMS. The user receives the motor status, the water level of the paddy field and the soil moisture state and moisture content of the field, in that order.



motor on 0.44cm overflow
93.8416422287
-
Sent via Way2Online. Download
http://bit.ly/WAY22

Fig 12. Intimation sent through SMS

I. Computer Vision Module and Processing Component

The computer vision component of the system deals with the detection and diagnosis of any infestations or diseases in the rice field concerned. It requires an image acquired by the data acquisition tool or from the farmer himself as an input, and processes it to derive a usable form of action required for the farmer – fertilizer treatments to use for the successful purging of the infection. The way this is done is by looking for specific characteristics of diseased plants and leaves in the input image and matching them with known data to confirm or deny the presence of a disease. Rice blast is the most important disease to be looked at here, as it is consistently the most damaging disease to occur in a rice crop, causing millions of kilos of yield to go waste.

The most powerful tool for image processing purposes currently is the OpenCV module developed by the OpenCV community and hosted on GitHub. This module can be used with both Python and C++, and Python was chosen in this case for the ease of use in a Linux Ubuntu programming environment. It also merges well with all the other code the project uses.

J. Disease diagnosis through Image Processing

With the advent of image processing, automation has attained significant attention in the areas of medicine [13-17], agriculture [18], etc. In this work, image processing is handled in python language, making use of OpenCV and NumPy modules to process the data. The program works by utilizing a number of image processing techniques. A Gaussian blur is applied as a filter at the initial stage. A Gaussian blur is caused when a Gaussian function is used on an image. It is a technique which is popularly used in graphics analysis software, majorly to reduce image noise and reduce detail. The resultant image is a smoothly blurred image which is similar to viewing the same image through a translucent medium. Another technique called the Bokeh effect is produced by an out-of-focus lens or by using the shadow of an object under natural illumination. This technique finds use in computer vision algorithms as a preprocessing step to enhance image structures and processing at different scales.

Also used to refine the acquired image is dilation and erosion – These are a couple of useful morphological operations that aid in removal of a lot of visual artefacts in images by means of removing or introducing “holes” in the images – holes being the term to denote pop outs of the background against the foreground. It is observed that detecting a dark color such as brown is helped with erosion, which fills in part of the spots that were previously detected as part of the leaf itself by the imaging equipment. Thresholding is the process of extracting useful color components from the raw image. Different thresholding techniques were experimented with to obtain a reliable method to extract only the diseased portion of the leaf. This operation separates out portions of the image that match BGR values within a specified range, BGR being the denotation of a pixel in the Blue-Green-Red color space. A mask of the image is created that contains the brown/yellow components as the foreground and the rest as a black background, making it easier to draw contours. Contours are constructs that are used here to quantify the area of the concerned color in the image.

These are "drawn" over an image to efficiently quantify them, such as constricting them within structures such as bounding boxes and minimum area circles. These can then be used to calculate area. Since the contours are drawn on the mask of the image that already contains only the brown/yellow components, all the contours are significant to the diagnosing process. The area of each contour is cumulatively added and checked against the total area of the image (width x height). If this percentage is greater than a specific value, rice blast is detected as the disease, if not, brown spots is a likelier match. If the percentage of brown pixels is very much high, the disease diagnosed is sheath rot.

Finally, an AND operation of the mask and the source image is done to provide a visual representation of the brown components present in the image against a black background. Though this does not directly impact the diagnosis process, it acts as a visual aid to detect any obvious anomalies the program does not pick up. In order to detect yellow, the image is transformed from BGR color space to HSV as it showed better results than the default color space. HSV stands for Hue, Saturation and Value. The contours are drawn the same way on the HSV transform to obtain the total area of yellow components in order to diagnose the yellow mottle rot disease.

A detection of rice blast is treated best with Carpropamid chemical and better management of water. Also, eliminating any residue from the previous crop harvest will reduce the likelihood of rice blast from a very early stage. A detection of sheath rot is a harder process, requiring high amounts of gypsum or neem water treatment to effectively mitigate the damage. A detection of yellow mottle virus infection cannot be "treated" to cure – the only proven technique is to use better (virus resistant) varieties of rice, such as RMYV1 and RMYV2. A detection of brown spots is relatively easier to treat – a dosage of calcium silicate slag along with the use of better quality fertilizers is usually sufficient to curb the level of infection. Hot water treatment is also recommended, with a comfortable temperature of 53 degrees Celsius.

K. Disease detection

The diseases looked for are rice blast, sheath rot, brown spots and mottle virus, as statistically speaking they are among the worst damaging diseases to rice crops, costing lakhs of rupees every year in irrecoverable loss to farmers. The algorithm parses through the image bits sequentially to find appropriate HSV and BGR values that match the characteristic colors of the diseases (usually brown). According to the value in percentage of brown component in the image, the decision is made whether the leaf is diagnosed with rice blast or brown spots. An alert message pops up on the terminal window along with the appropriate steps to be taken to mitigate the effect of the disease in case of a positive diagnosis. The brown discoloration is found to work better with BGR values (blue green red) while the yellow components are more accurately detected in the HSV color space (hue saturation value). As a result, the code is virtually split into two parts, each working on a different mask (from a different color space) of the image. Following are images used for detecting different types of diseases and their corresponding mask on which contours are drawn to find the area (and by extension, percentage) of characteristic colors of the disease's infection. Figures 13 and 14 show the processing done on an image of a leaf affected by rice blast.

Fig 13: Image of rice blast affected crop

Fig 14: Brown contours drawn over Fig 13

It is seen that the brown components have been extracted from the raw image in Figure 13 and drawn as contours in Figure 14. The sum total area of these contours can be calculated to diagnose the rice blast disease. Figures 15 and 16 elucidate the same process for a brown-spots affected leaf.

Fig 15: Image of brown spots affected plant

Fig 16: Brown contours mask drawn over Fig 15

It is seen that the brown contours mask in Figure 16 has a lower percentage of brown as compared to Figure 14. Thus the threshold for a brown spots diagnosis is less than the same for rice blast. Figures 17 and 18 demonstrate the diagnosis process for the sheath rot disease in rice crops.

Fig 17: Sheath rot disease characteristic

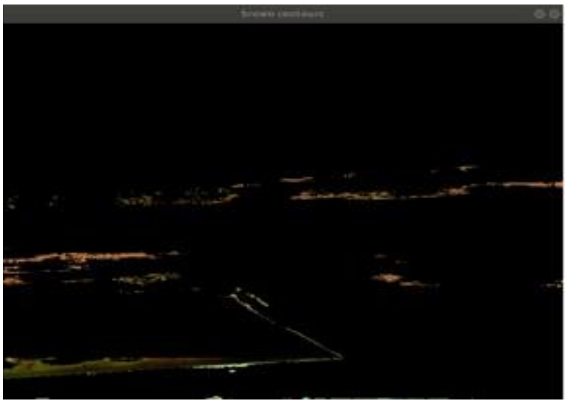


Fig 18: Brown contours drawn over Fig 17

It is evident that the brown components of the sheath rot affected stalk image is of much higher proportion than both rice blast and brown spots, leading to use of an increased threshold value for the positive diagnosis of this disease. The image chosen for this run was the sheath rot disease image (same as Figure 16). As a result of brownish yellow components, the leaf is also diagnosed with rice blast. This is as a precaution, as the range of characteristic colors ranges from dark yellow to Vandyke brown and there are instances of the same crop falling to multiple diseases at once. Based on the graphs shown above it is observed that the embedded electronic system's modules perform their respective tasks. Sensors measure physical parameters of the farm, relay the data to the cloud for further analysis. Any abnormality pertaining to the same is communicated directly to the user by means of both SMS and Email.The DHT11 sensor recorded the humidity and temperature of the field and it was observed that humidity was in the range of 64-65 percent. During the period of observation which lasted for 7 days the humidity spiked to an abnormal value of 70 percent on one of the days. The temperature of the field and the surrounding areas in its near vicinity was around 29 degree Celsius which is well within the optimum range of 25-35 degree Celsius. No abnormality was observed with regard to temperature anytime during the 7-day period. The water level of the paddy crop should be in the range of 2-5cm and the water level sensor module maintained the same during the observation period by periodically sensing the water level and deploying counter measures if needed. The percentage of moisture level in the soil is maintained in the range of 98-100 percent keeping in mind the fact that excess moisture can damage the crop. The data acquired by the sensors can be downloaded from the cloud in the form of an excel sheet, from which data can be analyzed by using various data analytics algorithms by virtue of which the use of key resources such as water, fertilizer, pesticide can be optimized. This process helps the farmers maximize the yield of their farm. The increased yield will help bridge the demand supply gap which will in turn solve the hunger problem being faced by many countries across the world. At the same time the farmers will experience a reduction in their cultivation costs, which will increase their profit margins. Hence, the use of this prototype engenders a win-win situation for all the stakeholders. The intimation techniques guarantee protection of crops from abnormalities which will ensure farmers reap tremendous benefits. The automation of processes will lead to very little intervention from the farmer's side. Also, the computer vision algorithm has successfully captured a leaf affected by Rice Blast and sheath rot disease. The treatment for the same, in the form of carpropamid and newer disease-resistant varieties of rice, is recommended to the user. The picture analyzed had 19390 pixels out of which the brown portion had 938 pixels resulting in 48.3 percent brown coloration in the sample analyzed. This indicates a high degree of brown discoloration which is a key symptom of Rice Blast. The module detects diseases at an early stage. This is an important benefit as this prevents the spread of the disease to other plants which in turn will save the field from getting affected and will ensure the farmer does not experience a loss. The power analysis of all sensors is done to compute the improvement in power caused due to the intelligent sensing algorithm. The embedded system thus designed is a low power device which can be used in areas where the supply of electricity is low. The results are shown in Table 3.

Table 3: Power consumption analysis

Sensor	Continuous monitoring	Intelligent monitoring	Percentage decrease in power
Temperature and humidity sensor	1200 mWh	958 mWh	19.5 %
Water level sensor	635 mWh	156mWh	75%
Soil moisture sensor	3.5 mWh	0.7mWh	80%

IV. CONCLUSION

In this work, a method to measure and control various parameters that affect the yield of a rice field was demonstrated. The parameters namely soil moisture, temperature, RH and water level were uploaded to a cloud, a Raspberry Pi was used as the microprocessor. The cloud could be accessed by a host specific username and password. In case of any abnormality, the farmer is notified via SMS and mail. If any diseases were detected, the corrective action is also sent as SMS to the farmer.

The use of this prototype will increase the yield of the field which will cater to the demands of the ever increasing population thus solving one of the biggest problems faced by people i.e hunger and malnutrition, at the same time this will help the farmer increase his/her profit margins leading to a better income which will lead to an improvement in the standard of living and result in a better life for the farmers.

The sensor operation is controlled through the intelligent sensing algorithm which ensures optimum sensor use which engender power saving and increase the life span of the sensors. The decrease in power consumption has been clearly highlighted. The power saving in case of the water level sensor and the soil moisture sensor is substantial and incase of the temperature and humidity sensor, there is a decrease and further decrease in power can be another topic for discussion and research.

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