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# Bayesian inference and Internet of Things based plant health care

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*Abstract*

***Advancements in the Internet of things (IoT) enable us to monitor and maintain a variety of devices in various sectors. Based on the literature available, we have found that there are umpteen IoT based methods proposed for plant health care involving hardware interfacing like sensors, micro-controllers, and cameras. The existing solutions also make use of mobile applications, web-servers, data-base for processing of information. This paper presents a novel and simple cost-effective Bayesian theorem based plant-health-care using sensors interfaced with raspberry pi. Our solution also provides users to watch and water the plant remotely, using a smart-phone via web-server. We have considered rose plant's favourable environmental factors for maintaining its health.***

***Keywords- IoT, Bayesian theorem, Data-base, Web-server, Sensors, Raspberry pi, Shell-script, C-Language***

## 1. INTRODUCTION

Agriculture plays a vital role in the progress of the economical stance of the country. It is a wonderful opportunity for us to use the technological advancements with enhanced internet connectivity [b4]. The Internet of things is the best example where we can design a smart system with the help of machine learning techniques [13][14][15].

This paper aims at designing an IoT based smart rose plant health care which effectively monitors the need and amount of water required for the rose plant.

We have obtained rationale for this novel approach from below facts on rose plant's good health.

- Roses need proper irrigation and good drainage to grow.
- Over watering leads to poor drainage, which in turn leads to lack of oxygen and hence yellowing of leaves.
- Avoid watering your rose bushes during the heat of the day. This lets foliage to dry off by the time the cooler evening air gets to them.

It is proven scientifically that over watering increases the stress in the plant leading to pollution of soil making the conditions not favourable for growth [1]. Hence our approach avoids over watering and proposes the right time of watering to the user with apt information of combination of humidity, temperature, and soil-moisture. Our novel approach uses the Bayesian model for inferring the suitability of the climate taking a significant number of likelihoods with sensor readings. We have implemented

this idea using raspberry pi, soil-moisture sensor, temperature sensor, humidity sensor for a single rose plant. Later we also explain about scaling this approach to a larger geographical area.

We also collected some basic inputs on photosynthesis process at three different times, in a day.

- During bright sunlight: Photosynthesis uses carbon dioxide and makes oxygen more faster compared to the respiration process which produces carbon dioxide and consumes oxygen. Extra oxygen is released into the atmosphere.
- During dim sunlight: Plant consumes all the dissolved oxygen generated during photosynthesis process. It also consumes all the carbon dioxide created by respiration. As a result, no gas exchange takes place with the environment.
- During complete dark: Only respiration process takes place in plants. Oxygen is consumed while carbon dioxide is released.[21]

## 2. LITERATURE SURVEY

Ibrahim, et al. [2] implemented layer based approach to monitor green house plants. This project is based on wireless sensors, IoT and uses switched Ethernet and WiFi. As this system is for large green house, author designs channel allocation schemes for reducing the interference. Zero packet loss is shown using riverbed simulations. Also fault tolerance at the controller level is introduced because controller of a greenhouse can take care of failed controller's greenhouse. For testing the reliability and steady states of greenhouses continuous Markov chains are developed.

Thakur, et al. [3], Implements a system to water the plants only when there is a need and also intrusion detection in agricultural field. This work is done by using Arduino, sensors and python coding and web applications. Author has mentioned that in future this work can be extended by the usage of pH sensor for better understanding of soil properties.

R.Nageswara, et al. [4], implements IoT based irrigation using raspberry pi, temperature sensor, humidity sensor and develops a web based application which helps farmers to see the output of the sensors and water the plant.

M.danita, et al. [5] explains about the green house monitoring and automatically by monitoring temperature, humidity and moisture content of the soil. Based on the readings raspberry pi helps in automatically watering the plants and closing/opening the sliding doors of the green house. Author has used ThingSpeak cloud platform to collect the data from sensors and display the real time data in the form of graphs.

Naresh, et al. [6] implemented a project for monitoring green house plants. In this project various sensors along with ARM processor is used to process the sensor data. Based on the sensor data relay is activated to plant the water.

C.Gajapriya, et al. [7], developed an ArduinoUno based automatic watering using temperature, humidity and soil moisture sensor. The sensor outputs are sent to the registered mobile using GSM technology. Based on the sensor readings watering the plants is done automatically. Author proposes future scope as extending this work for checking the soil nutrients and sprinkling the fertilizers automatically based on the need.

Sophocles Marios,et al.[8], discusses the challenges in implementing automatic plant monitoring using sensors and microcontrollers. Author provides the survey on existing sensor based automatic plant monitoring system and explains about the limitations of the existing system. Also provides an overview of precision agriculture methods.

K. Krishna Kishore, et al [9] proposes the method to monitor the growth of the plant and watering the plant automatically without the presence of a farmer. In this paper soil moisture sensor is used and also to detect the leaf disease kekre transform and variance methods are implemented.

Varalakshmi P, et al [10] proposes a method using raspberry pi, soil moisture sensor, temperature sensor, pressure sensor to check the status of the soil for watering the plants. Also interfaces the camera to raspberry pi and the combined results of sensors and captured image is analysed at the cloud storage and necessary message is sent to the caretaker through developed application. This paper has provided the method to differentiate healthy and diseased leaves by using artificial neural network method and efficiency of the ANN classifier is compared with SVM, KNN and random forest classifier methods.

Imran Ali Lakhiar, et al.[11], proposes an intelligent method using wireless sensors to detect fault and diagnose the same in an aeroponic cultivation system. In aeroponic cultivation soil is replaced by mist of nutrients and aeroponic cultivation needs a controlled environment for plant growth.In this method pH sensor, EC sensor, Light intensity sensor, Humidity sensor,CO2 sensor, Water level sensor, Timer sensors are used and the aggregated data is sent to the user through mobile phone using the mobile application.

Dr.J.Jegateesh, et al [12], performs the comparative study on the existing automatic irrigation system. In comparative study, the author mentions the type of technology used, type of software tools used, type of web applications/mobile applications used.

Bhanu K.N.et al [13],implemented IOT based agriculture using temperature sensor, soil moisture sensor along with Arduino UNO board.The output of the sensors are used in SVM classifier, KNN classifier and Naive Bayes Classifier. Author concludes that SVM provides an efficiency of 87.5 which is better than KNN and Naive Bayes classifier. Author uses ThingSpeak database. In future scope it is mentioned that the proposed method can be used to predict the soil fertility using soil fertility parameters.

Shibin David, et al. [14], implements and artificial intelligence based smart agriculture technique by gathering the physical parameters using temperature, soil moisture, soil pH and rain drop sensors and Arduino Uno controller. The objective of this paper is to predict if the soil is suitable for cultivating the crops and also looks at the amount of the fertilizers present in the soil. Using Naive Bayes algorithm the probability of a soil suitability for a particular crop is calculated. Author proposes the future scope as implementation of wireless modules and more sensors like Nitrogen, Phosphorus and potassium sensors which helps in finding the amount of nutrients required for healthy growth of plant. Author mentions watering the plants automatically using IOT techniques as another future scope.

In our paper we have extended this work [14] using Bayesian approach and we take care of remote plant watering of rose plant.

Himanshu Nandanwar, et al. [15] this paper provides review of existing agriculture techniques based on data mining and machine learning techniques.This paper explains about the types of machine learning techniques that could be used for agriculture irrigation. The classification under supervised, unsupervised and semi supervised machine learning techniques are explained.

Mohan raj I, et al. [17] discusses various technology based agricultural systems available and also builds a system for performing agriculture compared to conventional methods. Various smart agricultural technologies are compared based on technology used and based on hardware and software components used. Author uses a clustering algorithm. Author proposes methods to concentrate on crop growth and more productivity. The system alarms the farmer about the unfavourable weather and provides only the required amount of water to the plants hence helps in conserving the water.

K.A.Patil, et al. [18] proposes a model for small agriculture using IOT.Various sensors are used to get the real time data and through web application the details of the weather, crop and advice to the farmers is given.

Sanjeevini P, et al. [19] implements an efficient water usage for agriculture by using IoT and sensors. The analysis of WSN based structure is done based on SNR, throughput, and improved coverage area and minimum mean square error.

Marcu, Ioana, et al. [20], this paper explains agriculture and smart farming using ADCON. This process uses various sensors which provide various parameters which help efficient farming. The output of these sensors are sent to cloud and these outputs are analysed using various algorithms. Author uses solar energy to power the entire set up. Future scope can be looking at security threats to such systems.

## 3. METHODOLOGY

We have followed a very simple but efficient model of collecting sensor data and checking against optimal values. Based on the difference, we conclude the climate for rose plant as “suitable” or “not suitable”, using Bayesian approach of likelihood.

A brief background on Bayesian inference is discussed below.

Mathematically Bayes’ theorem is defined as:

$$P(A/B) = (P(B/A) \times P(A)) / P(B)$$

Where A and B are events,
$P(A/B)$ is the conditional probability that event A occurs given that event B has already occurred
$P(B/A)$ has the same meaning but with the roles of A and B reversed and $P(A)$ and $P(B)$ are the marginal probabilities of event A and event B occurring respectively.

So we have applied Bayesian inference, on the consecutive sensor readings taken every one hour as sampling rate. Once our Bayesian inference database gets accumulated, the inference of climate will gradually become stronger.

The optimal values of temperature, humidity and soil-moisture for rose plants are as mentioned in TABLE I. The ranges have been labelled as bad, fair and optimal accordingly for respective parameters. The sensor readings are taken every one hour.

TABLE I : Optimal Values of temperature, humidity and moisture for rose plant

Courtesy: University of Agricultural Sciences, Bangalore, India

1. Temperature = 18 - 25 degrees (Celsius)
2. Relative Humidity = 60 - 70 % (Percentage)
4. Moisture = 430 - 520 (Number with three digits range)

Inference of climate based on values:

Temperature (T)
T < 18°C || T > 25°C : Bad
T >= 18°C && T<= 20°C : Fair
T >= 20°C && T<= 25°C : Optimal

Humidity (H)
H < 60% || H > 70% : Bad
H >= 60% && H <= 65% : Fair
H >= 65% && H <= 70% : Optimal

Moisture (M)
M < 300 || M > 520 : Bad
M >= 430 && H <= 500 : Fair
M >= 500 && H <= 520 : Optimal

For each set of reading we conclude the suitability of climate based on labels' majority (Bad, Fair, Optimal). As mentioned in table-II, if any one of the parameters is optimal, then climate is taken as suitable else it is taken as not suitable.

TABLE II : Decision making of suitability of climate based on parameters' label.

| Temperature | Humidity | Moisture | Climate |
|---|---|---|---|
| Bad | Bad | Bad | Not Suitable |
| Bad | Fair | Fair | Suitable |
| Bad | Bad | Fair | Not Suitable |
| Fair | Fair | Optimal | Suitable |

The key point to be noted that, if the climate is suitable, then we will not water the rose plant. If the climate is not suitable and if the moisture parameter is bad, then we water the plant for 5 seconds. The reason behind this is that both temperature and humidity are not under our control as our specimen is not in a controlled environment.

We keep noting down the sensor readings and conclude the climate as explained above. Along with this process, we also apply start Bayesian inference till we get the probability of a suitable climate greater than 0.9 and then we stop using our redundant calculation of judging the climate based on labels.

The steps followed in gathering the data and processing it is mentioned below

- The test-bed collects samples of sensor readings every one hour. Sampled data for the first 10 hours of a day is in TABLE III.
- Readings are stored in flat file in the raspberry pi flash. TABLE VI is a actual flat file.
- The historic data is used to correlate the correctness of the model which we have followed.

Table III- First 10 sensor readings of the day

| Hour | Temp in degree Celsius | Humidity | Moisture |
|---|---|---|---|
| 0th | 21 | 82 | 300 |
| 1st | 20 | 86 | 320 |
| 2nd | 19 | 91 | 330 |
| 3rd | 19 | 65 | 390 |
| 4th | 18 | 93 | 410 |
| 5th | 18 | 74 | 440 |
| 6th | 17 | 70 | 500 |
| 7th | 18 | 88 | 510 |
| 8th | 19 | 64 | 510 |
| 9th | 22 | 42 | 600 |

Suitability of the climate is calculated corresponding to TABLE III. And it is mentioned in TABLE IV.

TABLE V provides likelihood of suitability of the climate when any one of the parameter is bad, fair and optimal accordingly for first 10 readings of the day.(Based on Bayes theorem).

TABLE IV- Suitability of the climate

| Hour | Temperature | Humidity | Moisture | Climate |
|---|---|---|---|---|
| 0th | Optimal | Bad | Bad | Suitable |
| 1st | Fair | Bad | Bad | Not Suitable |
| 2nd | Fair | Bad | Bad | Not Suitable |
| 3rd | Fair | Optimal | Bad | Suitable |
| 4th | Fair | Bad | Bad | Not Suitable |
| 5th | Fair | Optimal | Fair | Suitable |
| 6th | Bad | Optimal | Fair | Suitable |
| 7th | Fair | Bad | Optimal | Suitable |
| 8th | Fair | Fair | Optimal | Suitable |
| 9th | Optimal | Bad | Bad | Suitable |

TABLE V - Likelihood of suitability based on Bayes theorem

| Parameter | Status | Probability of Suitable climate | Probability of Non Suitable climate |
|---|---|---|---|
| Temperature | Optimal | 2/7 | 0/7 |
| Temperature | Fair | 4/7 | 3/7 |
| Temperature | Bad | 1/7 | 0/7 |
| Moisture | Optimal | 2/7 | 0/7 |
| Moisture | Fair | 2/7 | 3/7 |
| Moisture | Bad | 3/7 | 3/7 |
| Humidity | Optimal | 3/7 | 0/7 |
| Humidity | Fair | 1/7 | 0/7 |
| Humidity | Bad | 3/7 | 3/7 |

TABLE VI-Flat File

```
Time Stamp = Fri 10 May 09:17:01 IST 2019
Temperature = 27.0 Degree Celsius
Humidity = 14.0%
Soil Moisture = 957 Units
Temperature:FAIR
Humidity:BAD
Soil Moisture:BAD
Climate:NOT Suitable for Rose

Time Stamp = Wed 8 May 12:17:01 IST 2019
Temperature = 26.0 Degree Celsius
Humidity = 27.0%
Soil Moisture = 398 Units
Temperature:FAIR
```

Humidity:FAIR
Soil Moisture:OPTIMAL
Climate:Suitable for Rose

## 4. BLOCK DIAGRAM AND FLOWCHART

Block diagram in figure 1 gives the connections between all the hardware components used in our project .Also List of components used are mentioned.

- Raspberry Pi
- Bread Board
- DHT11 Temperature and Humidity Sensor
- MCP3008 ADC
- FC 28 Moisture Sensor
- 3V submersible water pump
- GoodSky Relay
- Interconnecting wires
- Small diameter pipe
- 5V External Power Supply
- Small Water Container

The list of software components used in our project are

- Raspbian Operating System With inbuilt Wi-Fi
- LINUX Kernel v4.4
- Apache Web Server with Apache2 Debian Default Package
- PHP script Version 5.3.2
- Version 5
- Shell Script- Raspbian OS Shell with LINUX Kernel v4.4
- C - Language with usual GCC license

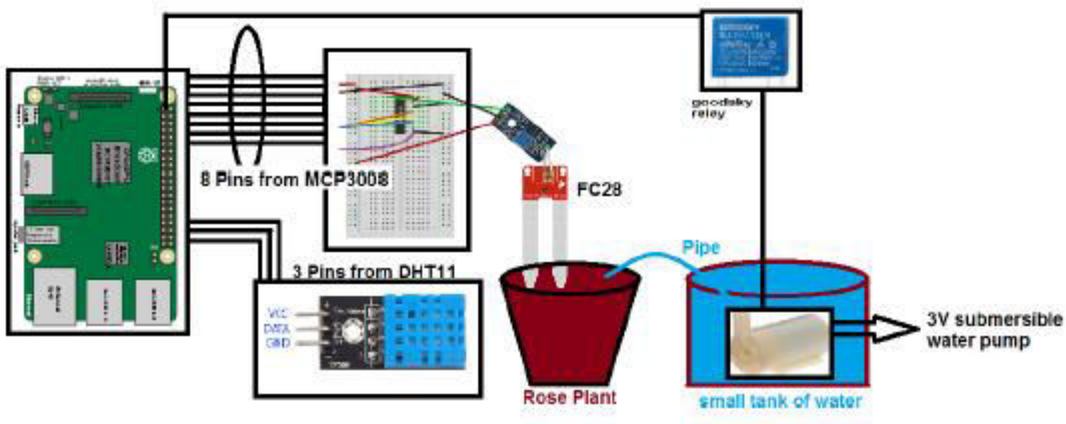


Figure 1. Block Diagram

Flowchart of the methodology is drawn in figure 2. When we switch on the entire set up following steps are followed.

The reading of temperature, humidity and moisture sensor are checked.The obtained sensor readings are updated to the Bayesian database. Here we apply Bayesian prediction to decide the suitability of the weather.Before prediction is done, the database is updated with few training sets.

The probability of suitable climate is checked based on sensor reading and Bayesian prediction .If the value is less than 0.9 (Maximum value can be 1.0) then check the moisture content of soil. Instead of watering the plant directly from predicted value we check the soil moisture and based on the need we water the plant. If moisture content is sufficient for plant then we wait for another hour.

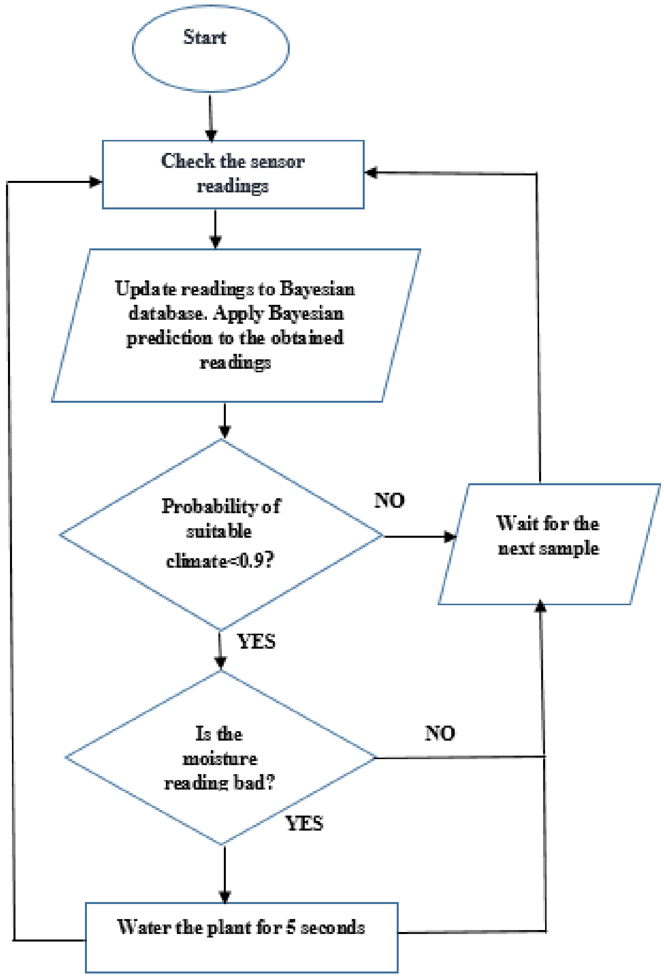


Figure 2. Flow Chart

## 5. RESULTS

When we analysed the data, we understood that, during day time, before noon, the climate was observed to be suitable for rose plants. After noon onwards till evening, the climate was observed to be not suitable for rose plants. The evening and night climate was observed to be suitable for rose plant. Sometimes the midnight climate was not suitable for rose plants.

The humidity was out of control taking our test-bed into consideration, as we do not have a controlled environment. At 21:17:01, Night the temperature, humidity and soil moisture came back to normal. From 11:17:01 to 20:17:02, the soil moisture started getting down, with humidity.

At 21:17:01, we watered the plant, by which the moisture content came back to normal starting from fair and then reached to optimal after subsequent hours.

This exercise let us know, the last point of the day, at which we can water the plant. After this we don't water the plant, irrespective of soil moisture getting bad. As the night starts the plant starts only the respiration process and stops photosynthesis. Again, from morning after 6:00 AM, we check all the values of the sensors and start watering if a decision is found to be not suitable for the rose plant.

We have obtained the graph of Time versus Humidity, Time versus Temperature, Time Versus moisture content throughout the day. We have also plotted the graph of Time versus Climate. Which are as shown in figure3, figure4 and figure 5.

The web server is accessed through mobile by the user. The image of the same is shown in figure 7. Web server is built using Apache web server with Debian package.

We have placed the all the necessary code that we have written to successfully complete this project in Github. It can accessed through this link . ***https://github.com/ashagh/pirose***

Results of our experiments are already mentioned in TABLE III to TABLE VI. The details are mentioned in methodology. As this approach is economical this can be extended for landscaping having the monitor for only one plant. Because the temperature and humidity will be same for all the plants.Only the moisture will be in our control. Moreover the landscaping area will have the same moisture content as our specimen.

## 6. CONCLUSION

In our project we have implemented the health care for only one particular type of plant that is Rose plant. Many existing approaches implement a general plant health care system which may not show a good efficiency because requirement of each kind of plant is different. Hence we understood the need for the healthy growth of the rose plant and accordingly designed a hardware using controller and various sensors. In our approach we don't water the plant just by looking at moisture content of the soil. To make this system efficient we have used Bayesian approach. Bayesian approach will reduce the redundant calculation for suitability of climate using sensor readings again and again.

This implementation can be extended to large number of plants, and it can extended to green house plants in future.

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