Smart Agriculture using IoT & Filtering Technology

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***Abstract*—This paper focuses on the idea of smart agriculture. The main idea of this project is to make a smart irrigation system that updates live data using Internet of Things(IoT) technology. IoT technology helps to retrieve data from the sensors such as Temperature, Humidity, Soil Moisture. All these sensor values will be accessible to the farmer through a web application. This web application helps farmers better understand the requirement of water content in the soil which will eventually help in better irrigation followed by better crop production. The web application comprises three display sections, each displaying temperature, moisture & humidity values, and a manual button has been included for scenarios when there is an abundance of water due to rainfall. In such cases, alerts will be generated and the farmer can dig a way for excess water removal.**

The temperature sensor values are further processed for filtering out the noise by performing the Kalman Filter technique using Processing IDE application by Arduino. After filtering the noise we get smooth values and these threshold values are passed into a decision tree algorithm which, based on its rules, decides whether the water pump should be switched on or off.

***Keywords*—Kalman filtering, Precision Agriculture, Web application.**

I. Introduction

Agriculture plays an important role in the development of the economy. In ancient times it was only a mode of food and fodder production but with the advancement of technology now it is also a crucial mode of employment. In India, the share of agriculture and their related sectors in GDP has increased to 19.9% in the year 2020-21 from 17.8% in the previous year[**1**]. Hence working on agriculture advancement is much needed for the development of an individual and as well the country. This can be done with the help of emerging technologies. One such technology is the Internet of Things(IoT) which has made life much easier by its ability to automate things and interact with devices. A few of the many reasons to focus on improving crop production are an increase in population, decrease in resources, increase in manpower, etc. Henceforth utilizing this opportunity for developing agricultural devices would help in decreasing human effort and yield better production. These technologies can be used in the entire life cycle of food production, storing, distribution, and consumption which will lead to less wastage and food safety for people.

This paper focuses on developing a kit that will consist of sensors such as Temperature, Humidity, Soil Moisture. All the data obtained from sensors will be filtered by using Kalman Filtering. Further, the values obtained from filtering techniques would run in a decision tree algorithm which will predict the conditions of soil or weather and perform further tasks as per the decision tree rules provided.

II. Technologies used

A. Internet of Things

Internet of Things is an arising technology that holds the power of connecting to devices, interacting with them, or controlling them. IoT technology uses both hardware and software to control devices. It has been used for small automation such as the automatic doorbell, automatic fan, etc. But now due to its beneficial qualities, it is being implemented in almost everything. Some of the examples are smart cities, smart devices in the health sector, drone delivery, location sensors, Data Analytics, Smart Homes, Wearables, and many more.**[2]**

Similarly, IoT in agriculture will help farmers in real-time monitoring. They can get updates about their crops from anywhere in the world. With live updation of data they can get better insights and can predict issues before in-hand. It will also be useful for research purposes. It can be done by storing the sensor values. Few of the applications of IoT technology combined with other technologies include -

1. Monitoring weather conditions: This is the most important factor for better crop production. Because if we have the wrong temperature or moisture or humidity the crops will eventually die.

2. Smart devices such as weed cutters, drip irrigation.

3. Livestock monitoring

4. Crop management: By knowing the contents of soil we can provide necessary fertilizers and nutrients.**[3]**

This project uses the internet for the live-updation of data and stores it for further reference.

B. NodeMCU as a local webserver

An important part of IoT technology is the transmitter section. For transmitters, we have two options ESP8266 and NodeMCU. The reasons to choose NodeMCU instead of ESP8266 are mentioned below.

ESP8266 is a Wi-Fi module that is available at a low cost. This helps the micro-controllers connect to a Wi-Fi network and establish a simple TCP/IP connection. It has a Tensilica L106 32-bit RISC Microprocessor running at 80 MHz. The memory is distributed as follows: 32 KB instruction RAM, 32 KB instruction cache RAM, 80 KB user-data RAM, and 16 KB ETS system-data RAM. The pin diagram, structure along more features are given in its datasheet. The voltage (V_{cc}) that this ESP8266 supports is 3.3 V and this can handle up to 3.6 V at specific conditions.

The examples given in Arduino IDE such as blinking LEDs are very helpful for understanding the working of ESP8266. After going through the sketches related to Wi-Fi networks, the connection was built. Then the ESP8266 was programmed to behave as a local web server so that the commands would be easily transmitted through HTTP requests.**[4]**

As mentioned, ESP8266 can handle up to 3.6 V without causing any harm. But the amount of current obtained by providing this 3.3 V / 3.6 V is not sufficient for transmitting the Wi-Fi signals. When tried with the current generated by providing 5 V which will again be regulated using a 3.3 V voltage regulator (AMS1117), the signals were generated but the ESP isn't that productive and also releases heat which might lead to damage. To overcome this, NodeMCU is brought into the picture which is an ESP8266 with a perfect built-in voltage regulator in fig 1. Using this voltage regulator, the desired current can be obtained for the transmission of Wi-Fi signals.

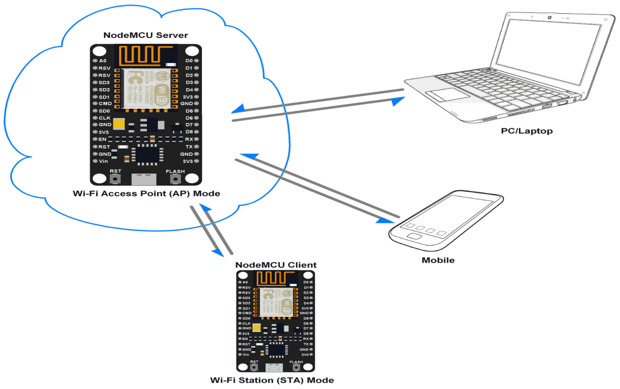

Fig 1: NodeMCU in two modes. Station(STA) mode and Access Point(AP) mode.

C: Kalman Filtering

The Kalman filter is a mathematical algorithm that processes at each step. It is an efficient and recursive model which inputs inaccurate data (including noise) and generates a statistically optimal estimate of the real system state, by developing a prediction model and an observation model. It has also been called the linear least mean squares estimator (LLMSE) because it minimizes the mean-squared estimation error for a linear stochastic system using noisy linear sensors. It has also been called the linear quadratic estimator (LQE) because it minimizes a quadratic function of estimation error for a linear dynamic system with white measurement and disturbance noise.**[5]**

In this, we have used the Kalman filter as it is the only practical finite-dimensional solution to the real-time optimal estimation problem for stochastic systems, and it makes very few assumptions about the underlying probability distributions except that they have infinite means and second central moments(covariances). Its mathematical model has been found to represent a phenomenal range of important applications involving noisy measurements for estimating the current conditions of dynamic systems with less than predictable disturbances.

The Kalman filter has enabled humankind to do many things that could not have been done without it. Its most immediate applications have been for the monitoring and control of complex dynamic systems such as continuous manufacturing processes, aircraft, tracking objects (e.g., missiles, faces, heads, hands), navigation, many computer vision applications such as stabilizing depth measurements, feature tracking, fusing data from radar, laser scanner and stereo-cameras for depth and velocity measurements and many more**[6]**.

For all the prior applications it is not always possible or desirable to make every variable that you want to control, and the Kalman filter provides the mathematical framework for inferring the unmeasured variables from indirect and noisy measurements. the It has become a universal tool for integrating different sensor and/or data collection systems into an overall optimal solution. Without this capability, the development of many complex systems (including Global Navigation Satellite Systems) may not have been possible.

III. Design of the System

The following are the sensors which we have used in our system.The sensors chosen are reliable and cost-effective with good build quality. They are -

A. Soil Moisture sensor

There are many types of sensors but we can vividly categorize it into resistive and capacitive types. We have used the capacitive type sensor instead of the resistive type because it doesn't corrode easily. Capacitive measuring comes with advantages such as it not only avoids corrosion of the probe but also gives a better reading of the moisture content of the soil as opposed to using a resistive soil moisture sensor and also there is a DC current flowing which causes electrolysis of the sensors. This sensor module consists of an on-board voltage regulator which gives it an operating voltage range of 3.3 to 5.5V. It is perfect when working with low-voltage Micro-controller units, both 3.3V and 5V.

This sensor works by measuring the changes in capacitance caused by the changes in the dielectric. This does not measure moisture directly (as pure water does not conduct electricity well), instead it measures the ions which are dissolved in the moisture which makes it more reliable and accurate. **[7]**

B. Temperature Sensor

It is a device which is designed to measure the degree of hotness or coldness in an object. DHT-11 temperature sensor is one such device which is of low cost and it can detect both humidity as well as temperature. This sensor comprises a dedicated NTC(Negative Temperature Coefficient) thermistor which means that the resistance decreases when temperature increases. The sensor is factory calibrated and therefore it is much easier to interface with other microcontrollers. It is a three-pin sensor and it can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%. The range of input voltage of DHT-11 temperature sensor is 3.3V - 5V**[8]**.

C. *Raindrop sensor:*

The raindrop sensor is a smart and low-cost tool for rain detection. The module consists of a rain-sensing pad and the control board which is separate for more convenience, a power indicator LED, and an adjustable sensitivity through a potentiometer. This modules working voltage is 5v.

The sensing pad detects any water droplets present on it while the control board reads all these signals. The raindrop sensor has a major application in the automobile industry. It can be used to monitor the rain and send closure requests to shutters or windows whenever the rain is detected.**[9]**

D. *Use of Sensors:*

The system consists of three sensors, one Temperature & Humidity sensor, one soil moisture sensor, and a raindrop sensor. It is connected to NodeMCU which acts as a web server. The readings from the sensor are displayed in the Google firebase and are further updated in the web application.

Ground-level application of this project can be done by using Arduino UNO R3 as a hub so as to connect many sensors to this. Also, we connected the temperature sensor to the Arduino board and used the Processing IDE application for the Kalman filtering technique**.[10]**

Our system consists of a web application. We have used Firebase which is Google's database platform used to create, manage and modify data generated from any application, sensors, etc.

Firebase platform is used as it sets the scope for Real-time database and authentication. The web application used in this project consists of a simple page with a manual button for irrigation and displays values of sensors mentioned above as in Fig 2.

The sensor data keeps updating every 1 minute in the web application.

Fig 2: Web application with sensor data.

IV. Data Analysis

In this system, data is monitored and noise is filtered from the data and it'll further be passed into a decision tree algorithm to perform tasks as per the decision tree rules included in Table-1.

A. *Monitoring of sensor data*

Real-time live data is continuously being monitored through all three sensors. General values of the temperature, humidity, and soil moisture sensor are updated in the web application. For Kalman filtering it generates in the Processing IDE environment we can copy-paste it in the excel sheet for reference. There is an option of manual switch which the farmer can use in case of emergencies.

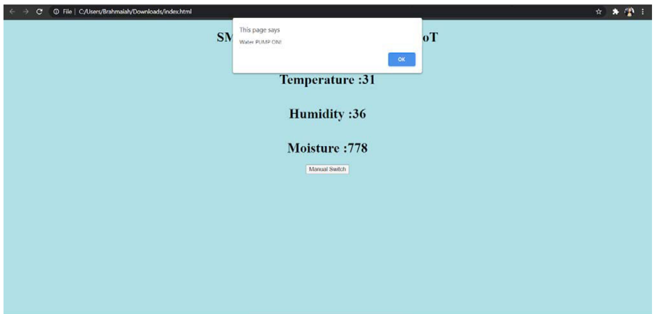

Fig 3: Manual switch function in web application.

B. *Kalman Filtering*

Generally, the sensor output voltage which we receive from the temperature sensor is noisy. So to reduce this noise we use a Kalman filter.**[11]**

Process of Filtering is as follows:

For each time step t:

- To predict the next state:
  $x(t) = F * x(t-1) + B * u$
- Predicting Next Covariance:
  $P(t) = F * P(t-1) * F^T + Q$
- Computing Kalman Filter Gain:
  $K = P(t) * H^T / (H * P(t) * H^T + R$
- Update the state estimate:

$$x(t) = x(t) + K * (measurement(t) - H * x(t))$$

- Update covariance estimation:
  $P(t) = (I - k * H) * P(t)$

$$x(t) = F * x(t-1) + B * u + Process\ Noise$$
$$z(t) = H * x(t) + Observation\ Noise$$

Our state vector is just the output reading of our temperature sensor:

$$x(t) = [sensor\ output\ voltage]$$

Assuming the temperature would not vary quickly i.e, temperature right now is the same as the temperature a short moment ago.

$F = 1$

There is no control input to the system

$B = 0$

The output voltage is the only observable voltage

$H = 1$

Process Noise has covariance Q

Observation Noise has covariance R

We have assumed the process variance is very low

So Set $Q = 1e - 9$

We can adjust this later through experimentation to obtain the desired filter performance.

Now to determine the R , the variance of Raw sensor measurements should be done by pasting the data of raw voltage readings into Excel and computing the variance.

$R = 1.12184e - 5$

The computed variance will be used as the value R in the Kalman Process. By plugging these values into Kalman Process equations,Kalman equations reduce to:

$x(t) = x(t - 1)$

$P(t) = P(t - 1) + 1e - 9$

$K = P(t) / P(t) + 1.12184e - 5$

$x(t) = x(t) + K * measurement\ (t) - x(t))$

$P(t) = (1 - K) * P(t)$

We will notice the lag in the Kalman filter result as the temperature changes quickly. If the temperature change is faster then by increasing the process variance Q for example,$1e - 9$to $1e - 8$ we can achieve a more steady filtered result.

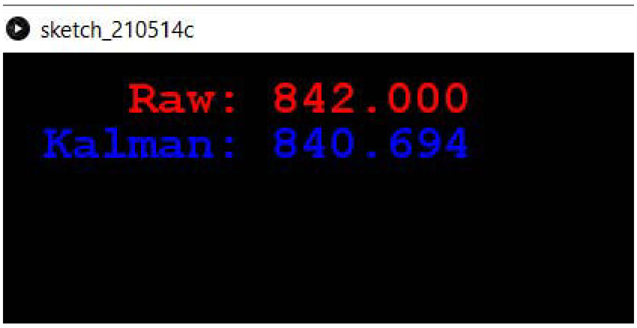

Fig 4: Filtered Kalman value of temperature sensor.

Note- As we have done this for temperature sensors it can be carried out for Soil moisture sensors as well.

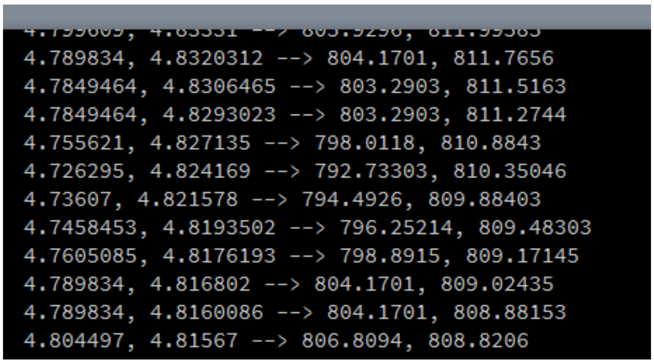

Fig 5: Sensor readings in Processor IDE application.

C. *Decision Tree*

Generally, after receiving the threshold value from the Kalman filter the system needs certain logic to do automatic irrigation.

So rules for decision tree implementation are:

Soil Moisture Value	Raindrop value	Decision	Result
<300 & <500	<300 & <500	No Rain	Pump "ON"
<300 & <500	>500	Raining	Pump "OFF"
>300 & <500	<500	No Rain and adequate moisture	Do nothing
>500	>500	Raining and moisture is increasing	Alert to farmer

Table - 1: Decision tree rules

*Note - Maximum value noted for raindrop & soil sensor ~ (980) and Minimum value noted for raindrop & soil sensor ~ (130)

Conclusion

This system consists of a kit that has low cost and highly reliable sensors. The function of the system is it updates sensor data which is useful for real-time monitoring. It performs automatic irrigation based on the decision tree rules provided. Before passing the sensor values directly into the tree they'll be filtered out of noise by a popular and yet promising technique called Kalman filter. The system also provides a manual button in case of emergencies such as sudden rain or storm. It has been implemented with emerging IoT technology. It also used NodeMCU as a local webserver which lets us control the system with any wifi.

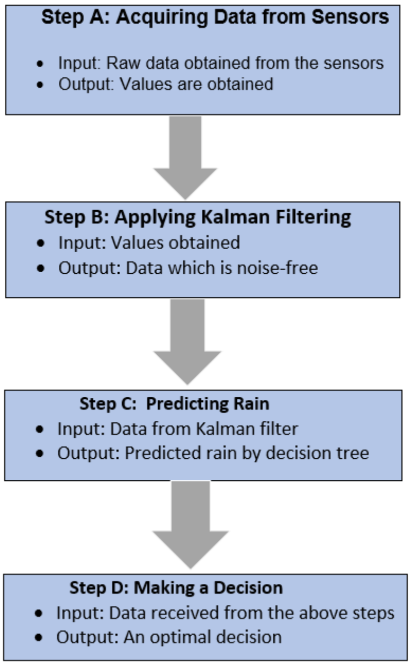

Fig 6: Flowchart of working of the system.

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