

An IoT Based Model of a Nitrogen Detection System for Soil Samples

Sheikh Sayed Bin Rahman
Faculty of Science & Technology
American International University
Bangladesh
sayedrahman015@gmail.com

Ishfaq Ahmed
Faculty of Science & Technology
American International University
Bangladesh
ishfaqahmed0837@gmail.com

Fahad Ahmed
Faculty of Science & Technology
American International University
Bangladesh
fahad.ahmed@aiub.edu

ABSTRACT

IoT plays an important role in smart irrigation system. Using new technology on agricultural field will be very much helpful in cultivation. Cultivation will be very difficult without knowing the important parameters of the soil and farmers also suffer financial losses. Plants cannot grow without the essential plant nutrients. Plants do need those nutrients to be able to grow and produce biomass. The nutrients that are required by crops in the largest amounts are nitrogen (N), phosphorus (P) and potassium (K). For that reason, they are often considered as the most important nutrients. This study provides a brief overview on the most important nutrient nitrogen (N) detection in soil. A portable device model proposed in this study that can be used to detect concentration of Nitrogen from a soil sample.

CCS CONCEPTS

- Sensor Application & Deployments
- Agriculture

KEYWORDS

Nitrogen, IoT device, NPK, detecting Nitrogen in soil, Smart irrigation system, Nitrogen detecting sensor.

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1 Introduction

Internet of Things (IoT) is a mechanism which connects different devices or objects in a shared network where each of them can communicate with each other with the help of internet connection. The population of the world is increasing at an exponential rate, to fulfill the requirement of population growth there is a need for increased crop production. To increase crop production fertilizers having predominantly and adequate

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nitrate (N), phosphate (P), and potassium (K) are essential. Improper use of fertilizers results into low yielding crops, fruits of poor quality, color, size, test and even quantity lags in vegetables. In China over-application of fertilizers has caused low fertilizer usage efficiency (~35% in average) resulting in low agricultural product quality, serious environmental pollution, etc. [1].

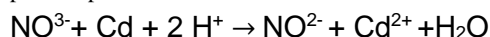
Applying the proper amount of fertilizer can help plants produce good yields and in better quantities. In order to meet the needs of a world which is constantly rising in need of food and food production. In order to develop and increase the quality and quantity of crops, fertilizers must contain sufficient nutrients, which is composed of micro nutrients such as Nitrogen (N), Phosphorus (P), and Potassium (K). These three elements are essential nutrients which helps in the growth of the plant in different ways [2]; the importance of Nitrogen is immense, due to lack of Nitrogen growth of leaves and vegetation is hampered [3]. Therefore, to get a proper yield, adequate amount of these micro nutrients must be applied. Moreover, the amount of fertilizers to be applied depends on the amount of micro nutrients present in the soil. Since these micro nutrients vary even on a small scale throughout a cultivated field, A lot of scientists and researchers are constantly trying and have attempted to develop the sensors to map these nutrient contents. Integrated crop management systems have been designed to study temporary behavior of NPK micronutrients[4]. Continuous monitoring of these micro nutrients along with humidity and pH of soil is leading to an automation in agricultural areas to improve crop productivity[5,6]. In the past, researchers have tried to develop device which will detect NPK by using various methods such as optical, electrical and electromagnetic, electrochemical, acoustic and mechanical[7].

In the current study, an aqueous solution of soil under test has been mixed with different reagents which will eventually change its color depending on the concentration of the present micro nutrients values. White light emitted from a color detecting sensor (TCS 3200) will fall on the solution and the reflected light is received by color detecting sensor will convert

the (R, G, B) values to electrical signals. Further using the threshold values which were earlier saved in the database of the microcontroller helps to detect the levels of micronutrients present in the soil sample. Therefore, an adequate amount of fertilizers can be applied which will help in better yield of crops and stop wastage of fertilizers.

2. Literature Review

By isolating chemically, nutrients can be found from soil. Nitrogen found in the form of nitrates. It can be extracted with a chemical extractant. Each nutrient can be combined with a known mixer. It will change to a specific color. Darker color indicating more amount of the nutrient. A chemical mixer will be used in the sample to analyze the amount level of each nutrient. An increase in color intensity indicating more amount of the nutrient. Cadmium is used to reduce nitrates (NO_3^-) to nitrite (NO_2^-). The cadmium is contained in the purchased Nitraver 5 (high and medium range) and Nitraver 6 (low range) powder pillows.



The Nitrite ions will react with the acid named sulfanilic acid to form an intermediate diazonium salt. An specific-colored solution is formed when coupled with gentisic acid. Color intensity of this sample is directly proportional to the nitrate amount of the water sample [8].



Figure 1: Color sensor (TCS3200).

The methodology used was a quantitative research on the phenomenon of how ions reflect back the complementary color of the light, as the ion absorbs the rest. The sensor used was a TCS3200 which is a color sensor that can operate at three different refresh rates of 2%, 20%, 100%. This sensor is especially useful for color recognition projects such as color matching, color sorting, test strip reading. It has an array of photodiodes with 4 different filters which are 16 photodiodes with red, green, blue filters and 16 photodiodes without filters. By selectively choosing the photodiode filter's readings, we were able to detect the intensity of the different colors. The sensor has a current-to-frequency converter that converts the

photodiodes readings into a square wave with a frequency that is proportional to the light intensity of the chosen color. This frequency is then read by the Arduino [9]. The light of the LED that acts as the source of the light is white, which contains every color frequency. An Arduino UNO microprocessor was used to read the data from the sensor and interpret it on the serial monitor.

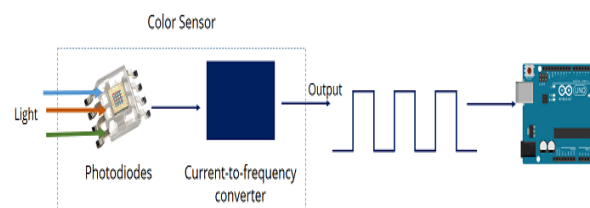


Figure 2: Color sensor (TCS3200) working flow.

3. Methodology

3.1. Preparation of solutions

Pure natural soil samples are used in the experiment. At first to make the aqueous solutions we used a little amount of soil and transfer to a beaker. A little amount of deionized water transferred to the beaker and also weigh out 0.1 g of calcium sulfate and add to the beaker. Then mixing all the content in the beaker and shake for 1 min. At last the contents of one NitraVer 5 Powder Pillow was added to the beaker and shake in a tube for some moment [8].

3.2. Color Detection

The color of the aqueous solution is detected with the help of a microcontroller and a color detecting sensor (TCS 3200 model) with a maximum distance of 3 mm between the soil sample and the sensor. The white light is being reflected

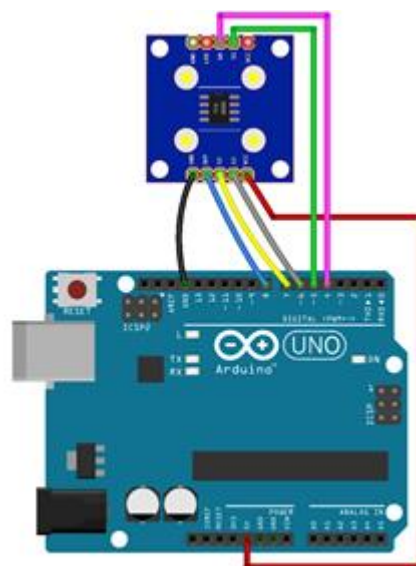


Figure 3: Connecting arduino uno and Color sensor (TCS3200).

by the solution and being consumed by the sensor which more precisely can detect the concentration of the color of the solution. Which helps in determining the amount of nitrogen in the given soil sample. The values are converted from analog to digital in the sensor and from the sensor an electrical signal of (R, G, B) values are sent to the arduino which enables it to work as an IoT device.

3.3 Our Proposed Architecture

Here the figure 2 exhibits the block diagram of the proposed architecture for the detection of nitrogen in the soil samples. Its consist of a color detecting sensor (tcs 3200) along with 4 high brightness 5mm LED lights which are used with different wrappers so that light gets well distributed and gets reflected back . The distance between soil sample and the sensor is 3 mm to get the proper value. Here we have to keep the photodiodes of the sensor very close to the liquid solution and all the study was done keeping this distance as constant , if we increased the distance then precise output for a single color was not obtained , and when we decrease the distance , LED's around the sensor came in contact with the experiment solution which causes diffused light, that is why 3mm distance has been considered as a constant and convenient . Wavelength bands emitted by this LED is relatively narrow. A mechanical chopper is not necessary as these LED are also amenable to direct intensity modulation. Often in different literatures , these fluorescent sensors are desired to be used in the design. Instead of LED , laser diodes can also be used however, because of the requirements of large drive current, required additional heat sinks are considered to be difficult to handle. The driving circuit of LED is made up of voltage to current converter, buffers and a subtracted. Here, light from the LED (white light) passes through the aqueous solution of soil sample. Depending upon the concentration of Nitrogen in the soil sample , the color of the concentration changes and white light of particular strength and wavelength gets absorbed and the rest are reflected back. Reflected light is absorbed by receiving sensor and then converted to an electrical signal using photodiode. The sensor output is calibrated in terms of deficient component values as per the standard color chart. The electrical output of the sensor varies as per the color of the solution. Comparing current values obtained with the microcontroller database values of Nitrogen component present in the soil sample is predicted. Afterwards this value can be sent to the server and farmers can use this information for proper input of fertilizers and stop wastage of fertilizers.

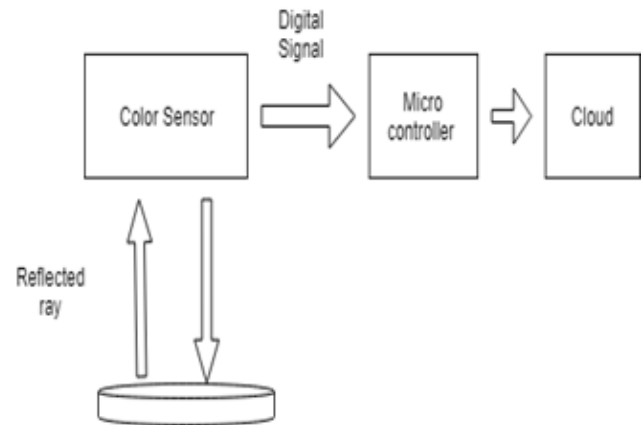


Figure 4: Block Diagram of the Experiment

4 Results And Analysis

Each sample will result in mg/L unit. Nitrate concentrations will be determined with the color compare box and display the result in the window.

Table 1. Nutrient level range in ppm.

Component	Low	Medium	High
Nitrogen	0 - 15	15 - 30	30+

Specific Color Comparator for Nitrate:



Figure 5: Specifically compare color for nitrate [8].

The experiment was going through several times to detect the color level. In this experiment 2% flicker rate has been used to determine the RGB value. The reason for using 2% flicker rate is precision, since with 2% flicker rate digital values for a single color varies from 0 to 2500 therefore more specific and precise data can be found on the other hand, if this is scaled to 20% or 100 % then digital values for a single color 0 to 255 and 0 to 25 respectively which is not efficient for finding a precise value for a single color. Around 100 reading of RGB values were taken for different level of concentration. The minimum value, maximum value, average value, standard deviation value were calculated from reading and use the minimum and maximum values as a range.

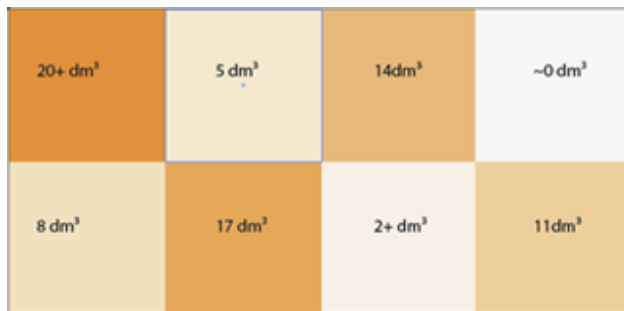


Figure 5: Gradient color comparator for detecting nitrogen concentration.

Usually a gradient is used on the comparator but in this work discrete values are approached so that color sensor can confirm the presence of nutrients more accurately. A table of colors which represent different values of concentration. These are not organized in ascending or descending order rather different colors are randomly placed.

5 Conclusion

As a conclusion, the IoT device built with LEDs and photodiodes along with arduino microcontroller as an alternative method for finding the amount of nutrients such as Nitrogen in the soil sample is successfully developed and tested. This study will aid the farmers as well as researchers in determining the amount Nitrogen present in the soil with a cheaper cost. The price of main ingredient for solution sample is about \$50 where we can make about 200 tests with it and the price of arduino uno and color sensor are \$9 and \$12 respectively therefore the cost for each cycle is about \$0.35 cents only which is feasible for farmers [13][14][15]. This will reduce the wastage of fertilizers as well as all the problems created due to lack of Nitrogen to the plants and will produce high yield of crops. This can be determined with the color sensor and the change of color in the aqueous solution depending on the concentration of the nutrients present in it. It provides the level of Nitrogen present in the soil into three categories such as low, medium and high by comparing the current R, G, B values of reflected light with the threshold

values of different color bands from database of microcontroller.

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