# Portable Soil Analyzer

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1st Chithralekha R.
*Dept. of Electronics and Communication*
*Rajagiri School of Engineering and Technology*
chitra.rjv@gmail.com

2nd Anupama K. R.
*Dept. of Electronics and Communication*
*Rajagiri School of Engineering and Technology*
anupama1998@gmail.com

3rd Deva Amritha A. S.
*Dept. of Electronics and Communication*
*Rajagiri School of Engineering and Technology*
devaamirtha98@gmail.com

4th Chippy Jerome
*Dept. of Electronics and Communication*
*Rajagiri School of Engineering and Technology*
chippyjrm@gmail.com

***Abstract*—The soil analyzer is a portable device which has features to collect soil samples from different parts of a given land and the samples are checked for parameters that are important in crop production.Movement of the system will be controlled by chain wheels powered by DC geared motor. The collected data values are cross checked against the threshold values in a database to provide proper information about the types of crops that are suitable to be cultivated in that land under study. This information can be properly channelized by an app so that the idea is rightly conveyed to the farmers or the land owners.**

***Index Terms*—Testing, Soil measurement, Sensor,Soil Analyzer,Soil moisture, NPK, Soil pH**

## I. Introduction

With the presently available technologies, measurement of macro nutrients in soil is a complex and time consuming process. Even with the support of agricultural department , it takes at least one month to analyze and measure soil parameters like nitrogen, phosphorous and potassium so t h farmers can make right decision about the crop to be cultivate in a given area.The basic idea of the paper is to overcome th constraint and enable instant value detection of soil paramete like nitrogen, phosphorous and potassium.
As a consequence of catastrophic flood in 2018, the soil textu has undergone vast changes in Kerala, thereby reflecti n significant declines in productivity. Lack of knowledge in farmers and failure in proper analysis are the main reasons of reductions in productivity. Analysis is a crucial step bef o proposal of the paper. Case studies are crucial in analysing h existing scenarios. Since this paper is based on an agrob ot, analysing the soil conditions is of ample importance.Since the idea was developed from the devastating effects post flood, the first step we took was to study the changes that have happened in the soil across various districts in Kerala.

## II. System Overview

The general overview of the system in fig 1. consists of a chain-wheeled rover having provisions for drill-bit and an integrated sensor assembly. Considering the forward motion of the rover, the drill-bit will be placed first followed by the sensor unit at a particular distance from each other. The basic working involves the linear-downward and rotatory movement of a drill-bit to create a hole in the soil, followed by the forward motion of the rover to the distance that equals the spacing between drill-bit and sensor assembly which is achieved by providing proper delay between the two stops ,and finally insertion of sensor assembly into the drilled hole.The different soil parameters like pH,moisture and elements nitrogen (N), phosphorus (P), potassium (K) (NPK) are obtained from the sensors and compared with an already created database having the optimal values to provide proper information about which crop can be cultivated in a given land with the measured values.

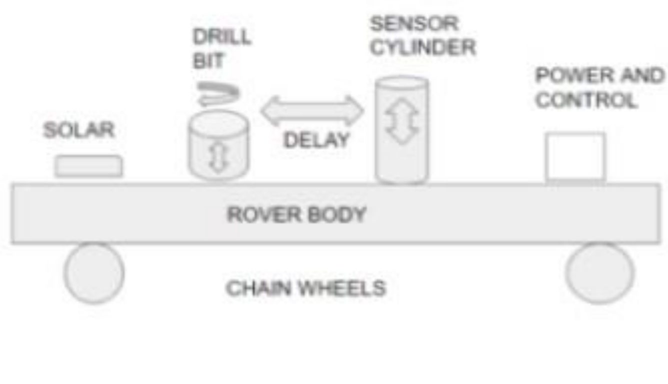


Fig. 1. Overview of the system.

Fig 2. represents the block diagram of the system.The raspberry pi-3 B form the heart of the system that consists of a 1.2GHz , 64 bit quadcore processor with built-in wifi, bluetooth and USB boot capabilities.Audio output, camera port, HDMI ports are also included. Multiple code could be run at a time, thereby enabling multitasking and it is powered by a 5uV USB supply.Four main sensors listed as below are

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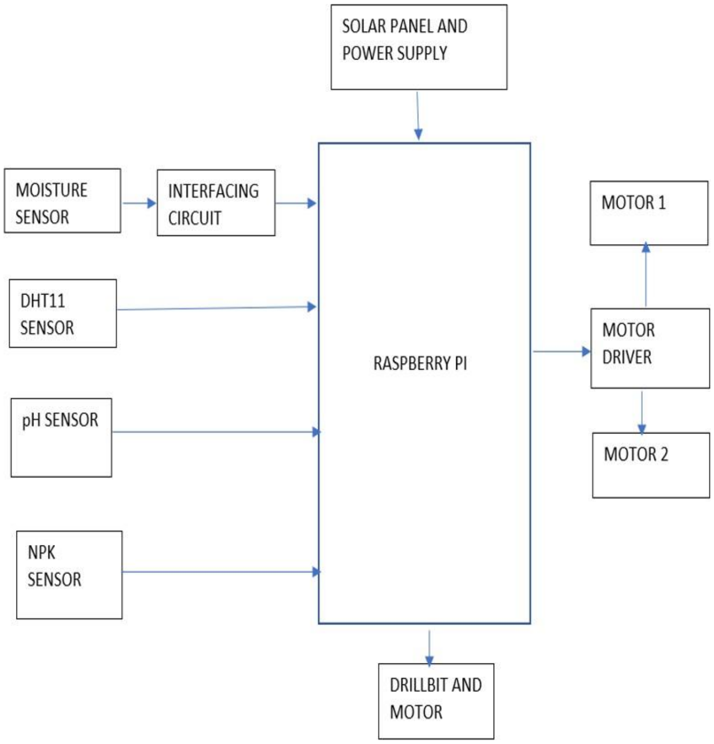


Fig. 2. Blockdiagram of the system

used:-

1) DHT11 Sensor, which is a basic low cost digital temperature and humidity sensor, that uses resistive humidity measurement component and NTC temperature measurement component. It provides relative humidity values in percentage(20 to 90 percentage) and temperature values in degree celsius(0-50 degree celsius).

2) Moisture Sensor that measures the volumetric content of water in the soil indirectly by using other properties of soil such as dielectric constant, electrical resistance.The module also includes a potentiometer that will fix the threshold value and the value can be evaluated by comparator LM393.

3) pH sensor has two electrodes- a sensor electrode and a reference electrode to measure the concentration of H+ ions in the solution.The electrodes are in the form of glass tubes, one contains pH 7 buffer and other contains saturated potassium chloride solution.

4) Teralytic is the world's first sensor for NPK measurement that consists of single sensor with 26 sensor probes reporting soil moisture, salinity and NPK at three different depths as well as aeration, respiration, air, temperature, light and humidity.However, for the purpose of this paper, we are considering test signals.

The measured parameters obtained from sensors are given to a cloud where it is compared with a database containing optimal values to serve the purpose of determining which crop can be cultivated in a given area from the obtained values.

Interfacing of various motors are also needed for movement of rover as well as linear movement of drill-bit and sensor assembly.Drill-bit has linear and rotatory movement whereas sensor assembly has only linear downward movement.The chain wheels of rover are powered by DC geared motor.L298N functions as motor driver which consists of H -Bridge configuration that allows speed and control of 2 DC motors at the same time.It can drive DC motors that have voltage between 5-35V.Mini-motors are used for linear downward movement of sensor and drill-bit.Ultrasonic sensors are used for obstacle detection.

## III. Implementation

### A. Sensors

The sensors were first interfaced on arduino and later on upgraded to raspberry pi.

1) Dht11- The device itself has four pins but one of these is not used. The 4-pin device will require a resistor (4.7K-10K) to be placed between Pin 1 (3.3V) and Pin 2 (Data). Data pin can be attached to any GPIO pin.Here pin 11 is used which corresponds to GPIO 17. It has a 10K resistor between pin 1 (3.3V) and 2 (Data/Out).Fig 3. represents the interfacing diagram of Dht11 with pi.

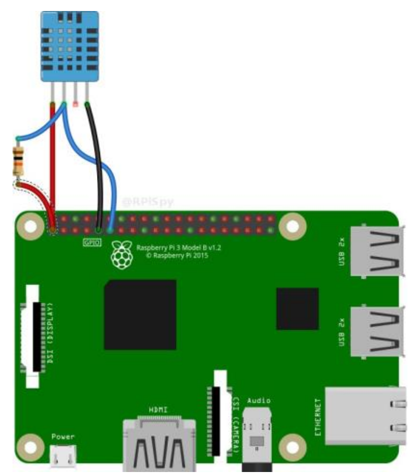

Fig. 3. DHT11 Interfacing with Raspberry Pi

2) To interface a moisture sensor with pi. the MCP 3008 IC is used, which is a 10-bit, 8-channel ADC (analog to digital converter).The MCP3008 uses the SPI bus protocol to receive analog input values from the Raspberry Pi. It features 8 analog inputs and uses four of the Raspberry Pi's pins, excluding the power and ground pins. It produces output values from a range of 0-1023 (Note: 0 represent OV and 1023 represents 3.3V).Fig 4. represents the interfacing diagram of moisture sensor with pi.

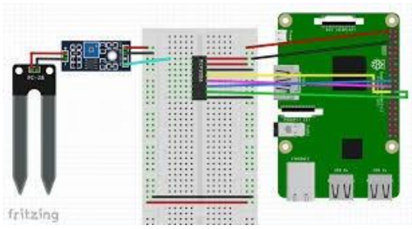


Fig. 4. Moisture Sensor Interfacing with Raspberry Pi

3) For pH sensor interfacing with pi, first we need to enable the I2C modules on the Pi. After this the GPIO pins 23 on the RPi are configured as the Serial Data Line (SDA) and Serial Clock Line (SCL) for use by the I2C protocol. The TX connection of the sensor circuit will connect to SDA (pin 2) on the Pi and the RX connection will go to the SCL (pin 3).Fig 5. represents the interfacing diagram of pH sensor with pi.

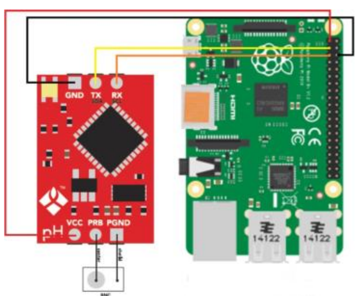


Fig. 5. pH Sensor Interfacing with Raspberry Pi

### *B. Rover Design*

The 2D sketched created initially were translated to three dimensional sketches with the help of software called CATIA, referred to as a 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development, including conceptualization, design (CAD), engineering (CAE) and manufacturing (CAM). CATIA facilitates collaborative engineering across disciplines around its 3D experience platform, including surfacing shape design, electrical, fluid and electronic systems design, mechanical engineering and systems engineering.

The 3D sketch was developed into physical structure by the process of 3D printing.The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created which is known as fused depositional modeling. The six main parts of the rover are body, cog, cog bracket inner, cog bracket outer, track midframe and track. After 3D printing , they were assembled to form the rover structure.

### *C. Navigation*

Navigation of the rover mainly involves obstacle detection by means of an ultrasonic sensor which is an instrument that measures the distance to an object using ultrasonic sound waves.It uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity. Most commonly used ultrasonic sensor is HC- SR04.

The HC-SR04 Ultrasonic Distance Sensor is a sensor used for detecting the distance to an object using sonar. It uses non-contact ultrasound sonar to measure the distance to an object, and consists of two ultrasonic transmitters (basically speakers), a receiver, and a control circuit. The transmitters emit a high frequency ultrasonic sound, which bounce off any nearby solid objects, and the reciever listens for any return echo. That echo is then processed by the control circuit to calculate the time difference between the signal being transmitted and received. This time can subsequently be used, along with some clever math, to calculate the distance between the sensor and the reflecting object.

For a larger field, a mere obstacle detection would remain insufficient. In such cases, a GPS module can be used to provide the way point locations of a field where the rover is supposed to move. Such a motion require careful planning and routing algorithm which will make the motion of rover smooth and power efficient. The algorithm should aim at taking shortest path from source to target. One considering the shortest path, obstacle avoidance and time efficiency , one of the best algorithm (A* algorithm) is chosen.

*1) A* Algorithm:* A * algorithm is a searching algorithm that searches for the shortest path between the initial and the final state.

Assume that a square grid is given and that has many obstacles, scattered randomly. The initial and the final cell is provided. The aim is to reach the final cell in the shortest amount of time. In this scenario, to use A* algorithm , the following parameters have to be considered.

g : the cost of moving from the initial cell to the current cell. Basically, it is the sum of all the cells that have been visited since leaving the first cell.

h : also known as the heuristic value, it is the estimated cost of moving from the current cell to the final cell. The actual cost cannot be calculated until the final cell is reached. Hence, h is the estimated cost. We must make sure that there is never an over estimation of the cost.

f : it is the sum of g and h. So, $f = g + h$

The way that the algorithm makes its decisions is by taking the f-value into account. The algorithm selects the smallest f-valued cell and moves to that cell. This process continues until the algorithm reaches its goal cell.

It does this by maintaining a tree of paths originating at the start node and extending those paths one edge at a time until its termination criterion is satisfied.At each iteration of its main loop, A* needs to determine which of its paths to extend. It does so based on the cost of the path and an estimate of the cost required to extend the path all the way to the goal. Specifically, A* selects the path that minimizes

$$f(n) = g(n) + h(n) \tag{1}$$

where n is the next node on the path, g(n) is the cost of the path from the start node to n, and h(n) is a heuristic function that estimates the cost of the cheapest path from n to the goal. A* terminates when the path it chooses to extend is a path from start to goal or if there are no paths eligible to be extended. The heuristic function is problem-specific, meaning that it never overestimates the actual cost to get to the goal, A* is guaranteed to return a least-cost path from start to goal.

## IV. Results and Conclusion

### A. Interfacing of Sensors

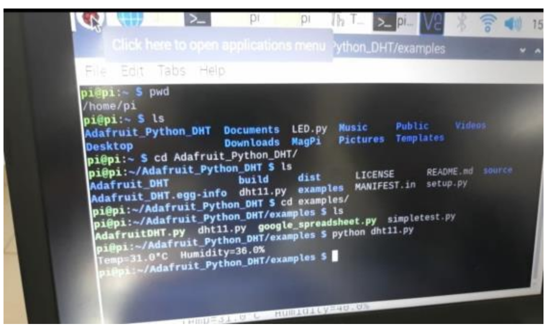


Fig. 6. Result of interfacing DHT11 on raspberry pi

*1) Dht11 Sensor:* Fig 6. represents the result of interfacing the Dht11 sensor on pi. As we are using the library Adafruit_DHT, we need to invoke the library with the Sensor and GPIO pin and print the values of Temperature and Humidity.The connections were made as per the circuit diagram and python code was executed to obtain the results.

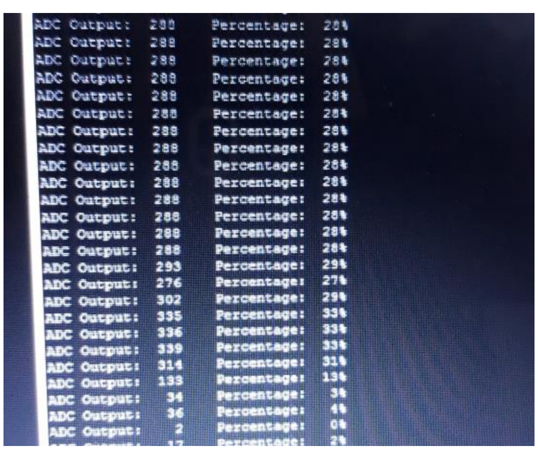


Fig. 7. Result of interfacing Moisture Sensor on raspberry pi

*2) Moisture Sensor:* The MCP3008 uses the SPI bus protocol to receive analog input values from the Raspberry Pi. It features 8 analog inputs and uses four of the Raspberry Pi's pins, excluding the power and ground pins.Fig 7. shows the result of interfacing the moisture sensor on pi.First, the SPI interface is enabled.The spidev library will help with reading the sensor values over the SPI interface. The numpy library is also required in order to convert the output values to a percentage. The output values we receive from the MCP3008 IC will be in the 0-0123 range which will be mapped to 0-100 for a percentage.

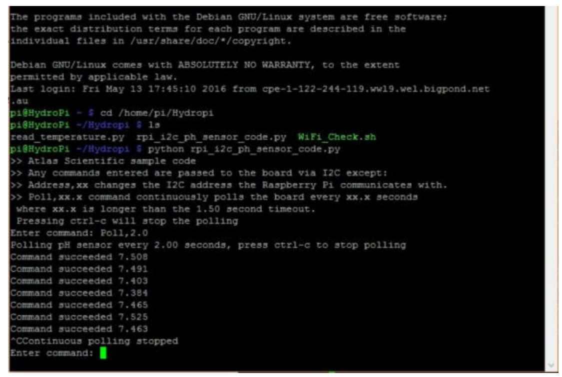


Fig. 8. Result of interfacing pH Sensor on raspberry pi

*3) pH Sensor:* The pH Sensor must first be calibrated. A pH 7.00 must be performed first and is known as the mid calibration point.Fig 8. represents the result of interfacing the pH sensor on the pi. I2C module is first enabled on the pi.The GPIO pins 23 on the pi are configured as the Serial Data Line (SDA) and Serial Clock Line (SCL) for use by the I2C protocol. The TX connection of the sensor circuit will connect to SDA (pin 2) on the Pi and the RX connection will go to the SCL (pin 3). We start by importing the required python modules. Next, we add the class code to interface with the pH circuit .Then the main code is run to obtain the result.

### B. MATLAB Simulation results for A* algorithm

A MATLAB code was written and simulated for verifying the A* algorithm. A target or a source point is initialised in the beginning. Then the obstacles which can obstruct the routes are virtually plotted. Finally, the destination point is also chosen. The code is then simulated to find out the best possible route.

Fig.9 shows the MATLAB simulation for A* algorithm. It ensures that the path chosen is the shortest among infinite paths availabe.Fig.10 shows another scenario where many locations are chosen. This resembles a large field where multiple way points are chosen using GPS coordinates. The algorithm is computed the same way as above. Initially two points are chosen as per the order in which the points are specified. Then the shortest path between those two are computed. Then the destination point in the initial case is chosen as the source point in the next iteration and the algorithm keeps computing the shortest distance between this point and the third way point.

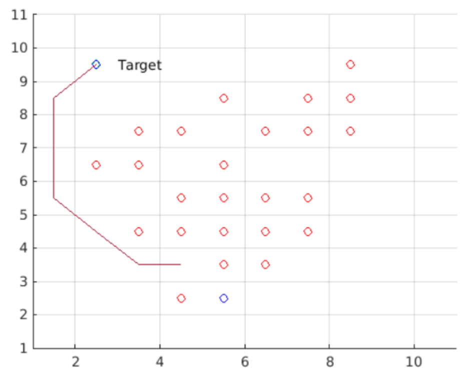


Fig. 9. MATLAB simulation for A* algoritm

This process continues until the entire area and locations are covered.

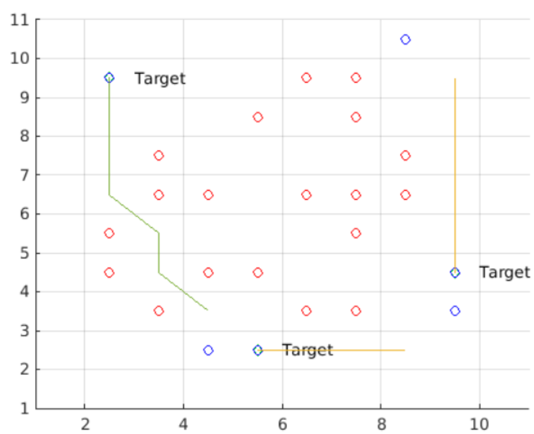


Fig. 10. Routing when many target waypoints are given

From the above results, it is seen that A* algorithm chooses the shortest path to reach the destination amidst all the obstacles. It can be modelled for a large field where a rover has to move between two points specified by the GPS location. Choosing the shortest path will make the rover energy and time efficient.

### *C. Rover Design*

Fig.11 shows the final assembled version of the rover.It was designed in catia software and then 3D printed in parts.It was then joined together to form a rover body.

### *D. Conclusion*

The implementation of the project 'Soil Analyzer' was done in sections. The fist section dealt with implementation and analysis of sensors. The pH sensor , moisture sensor and DHT11 ( temperature and humidity) sensor was interfaced with raspberry pi and analysed values for different soil types. Next section constituted the rover designing and assembly. The design was done in Catia software and fabrication was done using 3D printing technology. The final section dealt with the

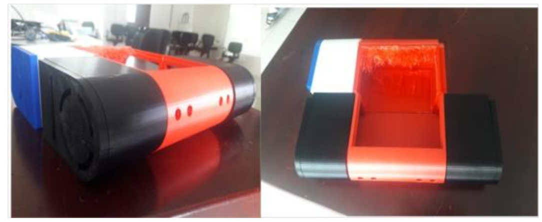

Fig. 11. Rover after assembly of 3D printed parts

navigation of rover which was implemented using ultrasonic obstacle detection method . A* algorithm was also simulated and verified in MATLAB for a shortest path routing.

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