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Double soil moisture detector for irrigation management using Arduino

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Abstract

The decision for the researchers and farmers regarding the exact time to irrigate plants is quite difficult; also many soil moisture sensors have been made using Arduino microcontroller for small farms in one depth, where this sensor doesn't give a complete vision for the farmers and the researchers in the effective root zone, for that this is research aims to develop a double soil moisture detector using Arduino microcontroller to give the growers an idea about the moisture content in the effective root zone, up to 40 cm depth, to determine the right time to start or end watering plants. The device has been assembled using two soil moisture sensors, with 20 cm in between, and programmed using IDE. The device has been tested and developed under different conditions of soil moisture. Generally, it was a good tool to detect the soil moisture in the effective root zone and a good tool to decide the time of watering plants with suitable water quantity.

Keywords: Double soil moisture detector, Soil moisture content, Effective root zone, Arduino

Introduction

Agriculture is the major resource of the living wage in Egypt, as well as more than 80% of water resources, are consumed in this sector. Water resources in Egypt are limited. Mismanagement of using irrigation water is a major obstacle to the newly horizontal expansion of the newly cultivated areas. Over irrigation is the main reason for waste water and causes some diseases, and negative production of the unit of land and used water. This is the issue we are going to deal with in this paper the regarding smart detection of soil moisture before and after using irrigation water, the first step for the smart watering system.

There are many methods to measure soil moisture such as the traditional method by hand, this method has many disadvantages, such as not being accurate. Many electrical devices have been developed to measure the soil moisture content, e.g. tensiometers, but they have a small range of tension measurement (0 to 1 bar), and require careful installation; and gypsum blocks, but their sensitivity is low in wet soils (<0.2 bars of tension), and installation of blocks requires coring (taking considerable time and effort). There are some accurate devices for measuring the soil moisture such as electromagnetic induction, but they are very expensive and sensitive equipment; and have interference from magnetic fields; and Neutron modification (Neutron probe), but it costs calibration which consumes time, needs high safety circumstances because it uses radiation.

The smart watering system can be defined as the artificial application of irrigating the soil after measuring the soil moisture content, using Arduino boards along with the moisture sensor which is the device that can monitor the soil moisture content, and then watering the fields or the landscape (Kumar *et al.*, 2020). So measuring the soil moisture content is the first step for precise watering according to the environmental conditions. The proposed system consisted of an Arduino Uno microcontroller platform and IoT system which enables farmers to remotely monitor the status of water level in the soil from the sensor values, making the farmers aware of the precious irrigation process as well as its dependent activities.

Devika *et al.* (2014) [1] used watering sprinkler system on Arduino board, which consisted of an ATmega328 Microcontroller to water the plants. Rhman *et al.* (2014**)** [16] represented a system of an Arduino Uno board which include an ATmega328 microcontroller, moisture sensors, temperature sensor, humidity sensor, and solenoid valve for smart irrigation.

Manoj and Udupa (2015) [4] reported that the Arduino board and soil moisture sensor based irrigation system proves to be a real-time response control system that monitors all the activity of the irrigation system. Singh *et al.* (2015) [7] mentioned that soil sensors can be used to detect the moisture of soil or judge if there is water around the sensor. Nagarajapandian *et al.* (2015) [5] reported the benefit of employing these techniques is to decrease human interference and still make certain appropriate irrigation water amounts.

Geetha *et al.* (2020) [2] emphasized that the moisture sensors measure the moisture level (water content) of the different plants. All of the developed soil moisture modules measure the moisture content at one level in the range of 10-20 cm under the soil surface, for that the aim of this research work aims to develop a double sensors soil moisture using Arduino microcontroller to measure the soil moisture content at two depths under the soil surface, helping the farmers to have an overview of their needs of watering their plants according to the soil moisture contents in the effective root zone (20 cm - 40 cm under the soil surface).

Materials and Methods

The soil moisture sensors modules components

Soil moisture is the content of water in the soil, and could be measured using a soil moisture sensor that has two conducting probes (Figure 1), based on the change in resistance between the two conducting probes, the resistance between the two conducting probes varies inversly with the amount of moisture in the soil, or the soil moisture sensor uses capacitance to measure dielectric permittivity of the surrounding medium in the soil; dielectric permittivity is a function of the water content. The sensor creates a voltage proportional to the dielectric permittivity, which expresses the moisture content. The sensor averages the water content over the entire length of the sensor. The sensor also contains an electronic module that connects the probes to the Arduino. The module produces an output voltage according to the resistance between the two plates of the probe and turns it to an Analog Output (AO). The same signal is fed to a LM393 High Precision Comparator (electronic module of the sensor) to be digitized and is made available as Digital Output (DO).

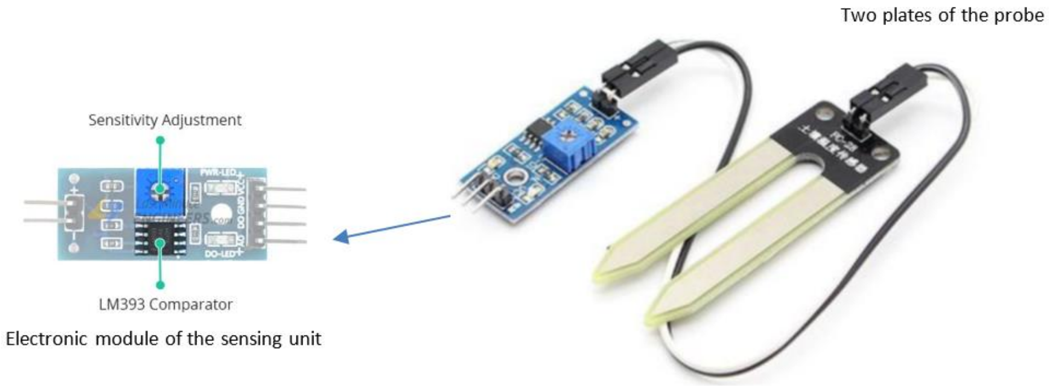

Fig 1: Soil moisture sensing unit

Arduino board

The soil sensor is attached to the Arduino Uno R3 microcontroller to transfer and collect the data, and LCD and its controller are attached to the Arduino board to display the data (Figure 2).

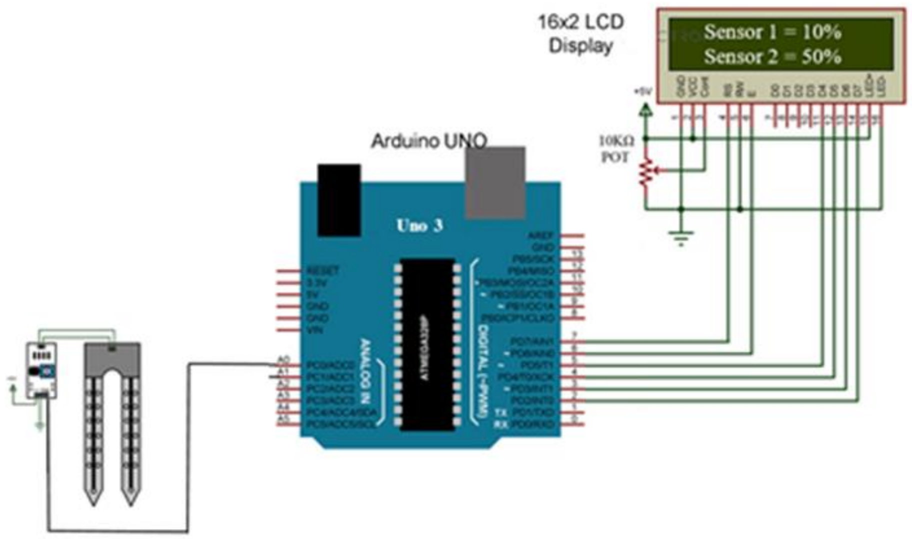

Fig 2: Interfacing Soil Moisture Sensor with Arduino UNO

Operating theory of the soil moisture sensor

The analog output of the soil moisture sensor is processed using Analog-to-Digital Converter (ADC). The moisture content in terms of percentage is displayed on the serial monitor (LCD), in the range of ADC values from 0 to 1023.

This can be represented as moisture value in terms of

percentage using the following equations.
Analog Output = (ADC value)/1023
Moisture in percentage = 100 – (Analog output * 100)
For zero moisture, we get the maximum value of ADC, i.e. 1023, which gives 0% moisture.

The developed double soil sensor using Arduino (DSSA)
Main components

Figure 3 shows the main components of DSSA which are Arduino Uno R3, two soil moisture sensors with their electronic modules, and the LCD with its microcontroller. The circuit's board has been programmed with IDE (Integrated Development Environment) software that runs on a PC, it is used to write and upload computer code to the Arduino board as a set of C/C++ functions which is the project code (Figure 4).

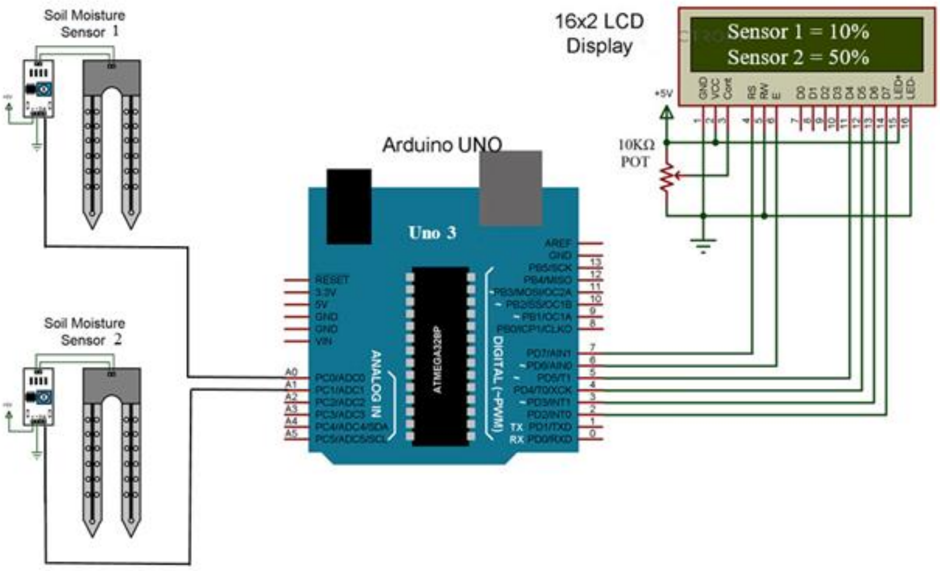

Fig 3: The developed double soil moisture sensor using Arduino

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd (0x27, 16, 2);
#define sensor1 A0
#define sensor2 A1
#define wet 320
#define dry 1020
void setup() {
  Serial.begin (9600);
  lcd.begin();
 }
void loop() {
  int value1 = analogRead(sensor1);
  int value2 = analogRead(sensor2);
  Serial.println(value1);
  lcd.setCursor(1,0);
  lcd.print("S1= ");
  lcd.setCursor(5,0);
  lcd.print(value1);
  lcd.print("=");
  int pre1 = map(value1, wet, dry, 100, 1);
  lcd.setCursor(10,0);
  lcd.print(pre1);
  lcd.print("%");
  Serial.println(value2);
  lcd.setCursor(1,1);
  lcd.print("S2= ");
  lcd.setCursor(5,1);
  lcd.print(value2);
  lcd.print("= ");
  int pre2 = map(value2, wet, dry, 100, 1);
  lcd.setCursor(10,1);
  lcd.print(pre2);
  lcd.print("%");
  delay (1000);
}
```

Fig 4: The Integrated Development Environment (IDE) code for the developed double soil moisture sensor using Arduino (DSSA)

Testing and calibration of the developed soil moisture sensor using Arduino (DSSA)

The calibration of DSSA has been made by comparing the readings from the sensors with the measured soil moisture content with the gravimetrical method in the lab after analyzing the soil mechanical properties (Table 1).

Table 1: The mechanical properties of the used soil in DSSA tests

Soil depth, cm	EC, dsm^{-1}	pH	Coarse sand	Fine sand	Silt	Clay	Texture class	Field capacity, %	Wilting point, %	Bulk density, g cm^{-3}
0-20	0.32	8.2	35.6	55.7	5.0	3.7	Sand	12.1	3.7	1.41
20-40	0.28	8.3	36.1	56.1	5.6	2.2	Sand	11.5	3.9	1.42

Soil samples have been collected at 20 and 40 cm depth at the same time of getting the readings of soil moisture from the developed sensor (every 2 hours, before and after the irrigation) using sandy soil, then the soil samples have been weighted and dried on 105 ºC for 48 hours, the moisture content (Θ_w, %) have been calculated using the following equation:

Θ_w = (wet soil sample weight, g - dry soil sample weight, g) / dry soil sample weight, g

The validation process for the developed soil moisture sensor has been made to test and calibrate the developed sensor (DSSA).

Results

Lab tests to develop the sensor

Many trails have been done to detect the soil moisture content (Θ_w, %) at two depths under the soil surface to test the response of the developed sensor under different conditions of soil moisture content in the lab, a variance has been noticed for the readings of the soil moisture percent almost at the same time, after many trails the cause of this variance was the erosion of the two conducting plates of the sensor. For that another two sensors have been manufactured using copper (from PCP plates) as shown in Figure 5. The new conducting copper plates were good enough to be used under field conditions, as well as have a longer life.

Field tests

Many tests were made by fixing the two sensors on a PVC pipe (1 inch in diameter) inside the soil to be the first sensor at 20 cm depth and the second one at 40 cm depth (the effective root zone of different plants). Another problem has been noticed for the sensing units of the sensors during measuring the soil moisture content under field conditions before and after the irrigation process, the sensors have failed because of the high humidity environment inside the probe pipe after many times of watering especially for the electronic module that connects the probes to the Arduino. So only the two copper probes of the sensors have been fixed on the probe pipe. The two electronic modules that connect the probes to the Arduino sensing units, the Arduino microcontroller, LCD, 9 V battery, and a power switch have been assembled in a portable device (Figure 5) and connected with the probe pipe using a wire connector then get the readings from the display for the two sensors. This modification helped to use many sensor probes only with one portable device.

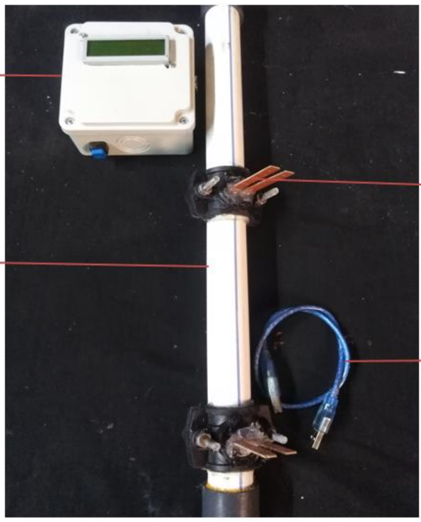

Fig 5: The developed soil sensor before fixing in the field

Validation of the developed sensor

In order to validate the readings of the soil moisture contents of the two sensors of DSSA, a comparison between the gained readings from DSSA and results of measuring the soil moisture content in the lab (gravimetric method in the lab, where the soil samples were taken at the same time of getting the readings from DSSA also at the same depths) have been made.

Data illustrated in Figures (6-a, and 6-b) show the comparison between the readings from the DSSA and measured data in the lab at 20 cm, and 40 cm depths, respectively. These comparisons were very good with only ±2 error which were very acceptable. Linear regression equations were gained under different field conditions, with high regression coefficient (more than 0.98). The same trend has been reported for the comparison between all data (Figure 7), that the developed sensor is a good tool to be used under different field conditions to have an overview of the soil moisture in the effective root zone with acceptable accuracy.

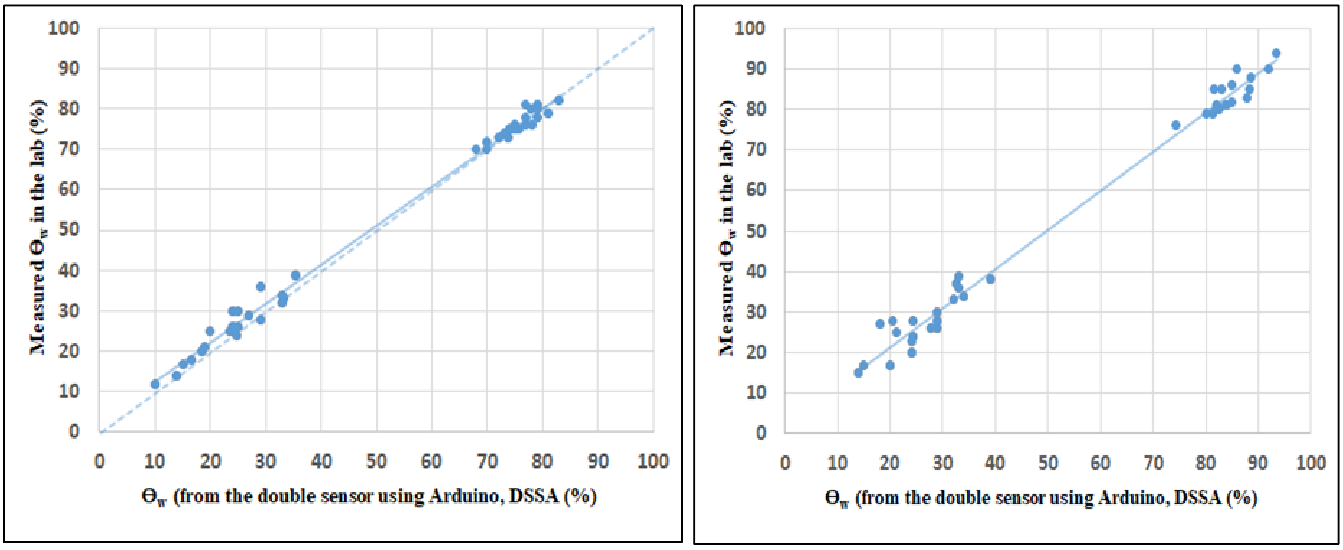

Fig 6: Calibration of the soil moisture content at (a) 20 cm and (b) 40 cm depth sensor using Arduino (DSSA) and reference Θ_w obtained by gravimetric method in lab using sandy soil type, 24 hours before and after irrigation process.

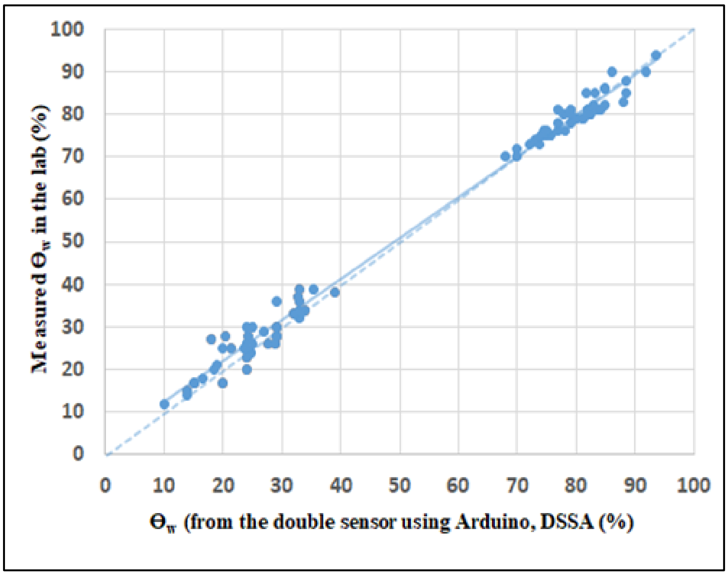

Fig 7: Calibration of the soil moisture content for all readings of the two sensors using Arduino (DSSA) and reference Θ_w obtained by gravimetric method in lab using two soil types (sand and clay soils), 24 hours before and after irrigation process

Conclusion

The Arduino soil moisture modules have been used in the small scale or the small gardens to detect the soil moisture content at one level under the soil surface. DSSA (developed soil moisture sensor using Arduino) has been developed to detect the soil moisture content at two depths under the soil surface which represent the desired effective root zone according of the plant type. DSSA have been calibrated and well tested under different conditions in the lab and the field, so it was a very good tool to have a good overview about the soil moisture content in the effective root zone.

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