ECE 445

SENIOR DESIGN LABORATORY

FINAL REPORT

A Remote Environment Recording System With Online Access Portals

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Team #17

XINCHENG WU
(xw80@illinois.edu)
YIZHOU CHEN
(yizhouc7@illinois.edu)
CHANGWEN CHEN
(cc105@illinois.edu)
DINGYUAN DAI
(ddai10@illinois.edu)

TA: Cao Zhijiao

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1 Introduction

1.1 Problem and Purpose

This project aims to develop a Remote Environment Recording System with Online Access Portals to enhance agricultural monitoring. Our system will integrate real-time soil condition measurement, wireless data transmission, solar-powered operation, and a web-based data visualization platform to provide users with a comprehensive and sustainable monitoring solution. By improving accessibility to critical environmental data and mirroring the physical environment in a digital space, this system can support both research and practical agricultural management.

Soil conditions, including temperature and humidity, play a crucial role in plant growth [1]. Inappropriate environmental factors are harmful to agriculture. For instance, unsuitable temperatures inhibit plant growth and reduce cell viability; Unsuitable humidity affects root growth and leads to malnutrition[2]. Therefore, for a plant production site, it is essential to check the condition of the soil. While existing remote monitoring platforms have already provided some solutions, they often fail to adapt to diverse environmental conditions due to hardware limitations and usually depend on non-renewable power sources. Additionally, they provide only static measurements rather than an interactive digital representation and analysis of environmental changes [3]. Therefore, we want to optimize the versatility of physical detection equipment and build a remote monitoring platform with digital twin modeling.

1.2 Functionality

To monitor the variation of space environments and build environment recording systems, we decided to focus on the local soil database. Functions mainly consist of three parts, including collecting information on the humidity, temperature, and flatness of soil; setting up a camera to supervise in real time; uploading all the data to the website platform; and visualizing it. Also, we use the camera to make a soil model of our experimental field and set this function on our online portal to help users better observe the soil flatness.

For better and more comprehensive detection of soil humidity and temperature, we are going to test soil at various depths separately. Set equal depth spacing can make the change of test data versus depth more intuitive while showing us the humidity and temperature in certain circumstances. In addition, the flat condition of the soil has also been taken into account. Considering that in some remote areas, it is hard to power these devices, and batteries may cause more degradation and environmental pollution, we will use solar power to supply all the facilities during this procedure.

In addition to the measures mentioned above, we are willing to set up a camera to supervise the test site in real-time. The camera should upload the real-time picture to the website to help the experimenters have a basic command of the field. Also, industrial production may help the controller decide whether the field needs to be irrigated.

Beyond that, we will make an online access portal and upload all the information we test on the website. This website can help us compare the change of these data versus time and give the users a clear tendency of change of the soil and environment data to help them make better decisions. Moreover, we will create a digital twin model that continuously updates environmental conditions, which allows users to visualize and analyze soil conditions interactively.

1.2.1 Benefits

The system enables remote and real-time soil and environmental monitoring for farmers and researchers. Also, it can improve decision-making for irrigation and crop management through predictive insights from the digital twin. Besides that, the system can provide a sustainable and low-maintenance monitoring solution through solar power.

1.2.2 Features

The features of our systems are: Self-sustained power using solar energy, eliminating external power dependency and multi-depth sensing, offering more accurate insights into soil conditions. Also, it can achieve real-time camera feed, enhancing situational awareness and Wireless data transmission, reducing the need for physical access. Besides that, our system has a user-friendly web portal and visualization, making data easily accessible and interpretable with digital twin modeling, allowing historical trend analysis and predictive modeling, and a Soil modeling model, reflecting the undulations of the soil on the online portal.

1.3 Subsystem Overview

1.3.1 Changes during the semester

Our project underwent several changes during the semester, which are also reflected in our block diagram.
In the figure, the first change is the refinement of the power supply module. We added more parameters, which are important for analyzing the stability and battery life.
The second change is the alteration of the function of the PCB in the camera module. Originally, it was planned to remotely control the camera. Later, we preferred that using the camera to assist in soil surface modeling was more important and thus eliminated this function.
The third change is the addition of the soil surface modeling function in the visualization module, which is precisely the important new function mentioned above.
The fourth change is not shown in the figure. Regarding the installation of the camera, we decided to use a modified clothes-drying rack combined with a rotating system to enable the camera to serve both monitoring and soil surface modeling functions.

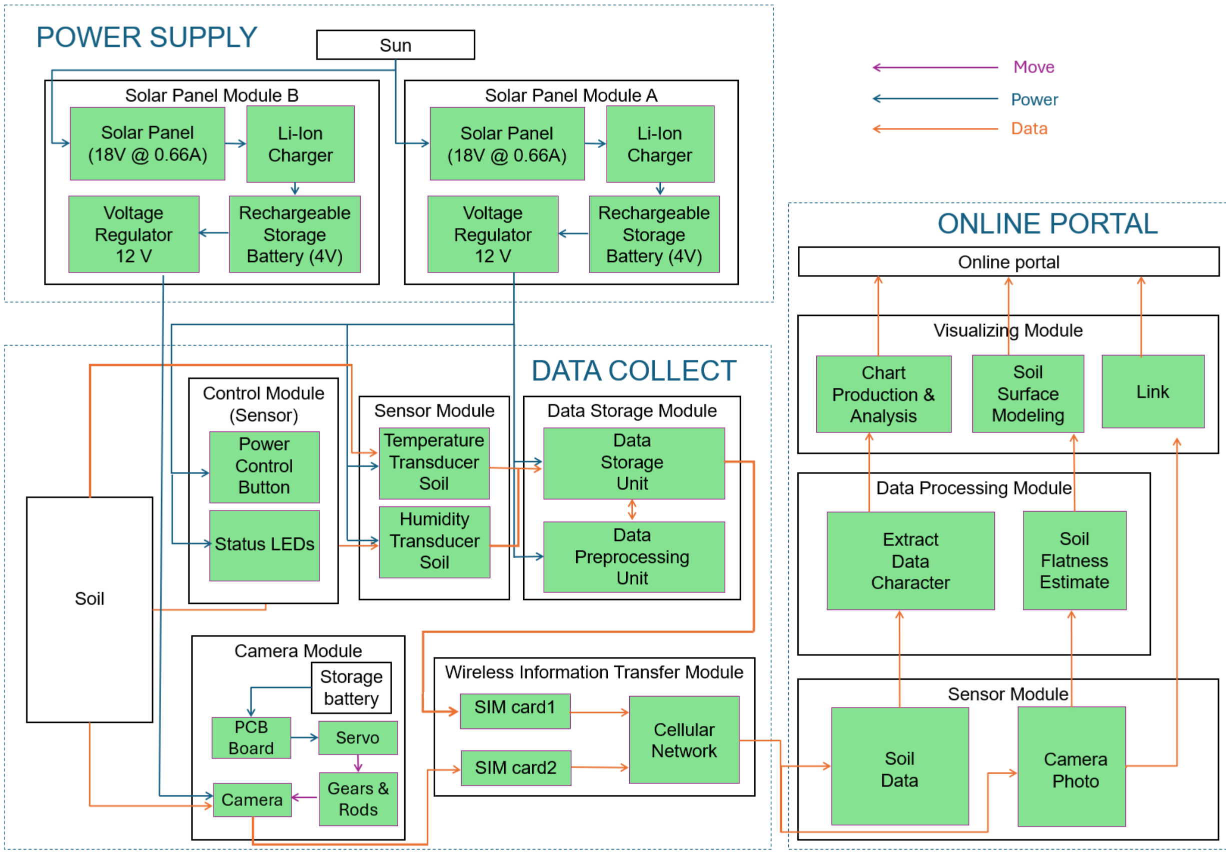


Figure 1: Block Diagram

1.3.2 Power Supply

The power supply subsystem contains 2 independent solar panel modules. Solar panel module A is set for powering the soil sensors, and solar panel module B is set for powering the camera. The function of this part is to convert solar energy to electrical energy, and after achieving this goal, this part will supply the power for the data-collecting module.

1.3.3 Data Collect

The Data Collect module contains 5 modules: control module, sensor module, data storage module, camera module, and wireless information transfer module. The function of this part is to use the sensors to test the temperature and humidity of the soil and use the camera to achieve two functions: soil modeling and supervision of the experimental field. After achieving these goals, the Data Collect part should upload all the information to part online portal.

1.3.4 Online Portal

The Online Portal subsystem serves as the primary interface for data storage, visualization, and analysis. It contains 3 modules: the sensor module, the data processing module, and the visualizing module. The data is transferred from the Wireless Information Transfer Module of the Data Collect Subsystem. This subsystem processes raw data into meaningful information, presenting it to the user through various graphical and analytical tools.

1.4 Performance requirements

The system must sample and record environmental data every 15 minutes and upload data every hour, including soil temperature and humidity readings from five different depths(1cm, 3cm, 5cm, 10cm, 15cm).

The camera must be able to achieve two functions: provide photos when the camera is at 0 degrees and 180 degrees; and rotate without any blind spots for surveillance.

The web portal should provide access to data from the sensor and camera, with visualization and digital twin modeling.

The result of soil modeling should correctly display the undulations of the soil and can be executed on our online portal.

The entire system should be able to run normally on solar energy through a 10W × 2 solar panel, ensuring continuous operation under variable weather conditions.

2 Design

2.1 Power Supply

2.1.1 Design procedure

For the power supply subsystem, we have 2 core modules: solar panel modules A and B. Both solar panel modules have a solar panel, Li-ion charge, rechargeable storage battery, and voltage regulator.

Solar Panel Module A is responsible for powering the sensors. The sensors draw 12 mA during measurement, 0.13 mA in sleep mode, and 100–800 mA when transmitting. The rechargeable storage battery provides 4 V, which the regulator boosts to the sensors' required 12 V operating voltage. The panel's peak output is

$$P = 18\,\mathrm{V} \times 0.66\,\mathrm{A} = 12\,\mathrm{W}.$$

The daily energy consumption is

$$E_{\text{daily}} < \frac{1}{30}\big(0.8\,\text{A} \times 12\,\text{V}\big) \times 24\,\text{h} \;+\; \frac{29}{30}\big(0.13 \times 10^{-3}\,\text{A} \times 12\,\text{V}\big) \times 24\,\text{h} \approx 7.68\,\text{Wh}.$$

Solar Panel Module B powers the camera, which draws a peak current of 0.58 A. In active use over the 4G network, the camera consumes 1.85 W, dropping to just 80 mW on standby. We plan to operate the camera for no more than eight hours per day on average. The module's rechargeable 4 V battery pack is stepped up to the camera's required 12 V by a high-efficiency boost regulator.

The panel's peak output is

$$P = 18\,\text{V} \times 0.66\,\text{A} = 12\,\text{W}.$$

The daily energy consumption is

$$E \approx 1.85\,\text{W} \times 8\,\text{h} + 80\,\text{mW} \times 16\,\text{h} = 16.08\,\text{Wh}$$

To guard against extended periods of rain, the camera module is equipped with its backup battery and can be charged at 12 V × 2.66 A (32 W). Zhejiang (approximately $30°\text{N}$) still enjoys sufficient solar irradiance even during the least-sunny winter months (Zhejiang has 10 hours between sunrise and sunset on Dec. 22), so the available radiation easily covers this load.

Although a large external battery could have powered the sensors, their fixed installation, partially buried underground, makes battery replacement prohibitively difficult. Moreover, an exposed outdoor battery risks water ingress and failure during heavy rain and incurs significant cost. For these reasons, we opted not to pursue this approach.

2.1.2 Design details

Solar Panel Module A: Module A uses an 18 V/0.66 A solar panel feeding a Li-ion charger that conditions and stores energy in a two-cell (4 V) battery pack. A high-efficiency boost regulator then steps the 4V battery output up to a stable 12V rail, which supplies the sensor's current and voltage requirement.

Solar Panel Module B: Module B uses an 18 V/0.66 A solar panel feeding a Li-ion charger that conditions and stores energy in a two-cell (4 V) battery pack. A high-efficiency boost regulator then steps the 4V battery output up to a stable 12V rail, which supplies the camera's 0.58 A operating current.

2.1.3 Diagrams and Schematics

2.2 Data Collect

2.2.1 Design procedure

In the data collection system, we have two core components: temperature and humidity sensors and a camera.

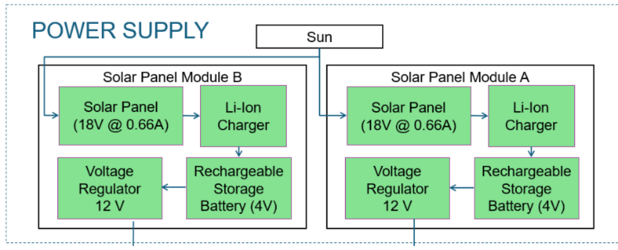


Figure 2: The Schematic of Power Supply Subsystem

For temperature measurement, several NTC thermistors were used, while for humidity measurement, several FDR capacitive sensors were used. The collected data is processed by an MCU and then communicated with a server via a SIM card to transfer the data. This is a mature and easy method, so we adopt it directly.
The resistance of an NTC thermistor will change when the temperature changes. It has an equation that.

$$\frac{1}{T} = A + B\ln(R) + C(\ln(R))^3 \tag{1}$$

Where T is the temperature of the soil, R is the resistance of the thermistor, A, B, C are Steinhart-Hart parameters, three dimensionless parameters for fixing.
The humidity of the soil can be calculated by the capacity of the FDR capacitive sensor.

$$C_{sensor} = G \cdot \epsilon_b + C_{stray} \tag{2}$$

$$\theta_v = -5.3 \times 10^{-2} + 2.92 \times 10^{-2}\epsilon_b - 5.5 \times 10^{-4}\epsilon_b^2 + 4.3 \times 10^{-6}\epsilon_b^3 \tag{3}$$

Where C_{sensor} is the capacity of the sensor, G is a geometry factor of the sensor decided by the properties of sensors, C_{stray} is the standard capacity in air, θ_v is the humidity of soil, ϵ_b is the permittivity.
The camera installation has gone through several iterations. Initially, we only wanted to use the camera for venue monitoring. A stand-up cabinet was designed to mount the camera and store other tools. After deciding to use a distribution box to store the tools, we prepared 2 fixing methods for mounting the cameras, suckers, and clips. Before producing a prototype, we decided to use the camera to help us model the soil surface.
There are many ways to accomplish this and initially, we had 3 options. The first option was to use 4 cameras directly and fix them individually with tripods, but the cost of 4 cameras might be too high; the second option was to build a track around the site to move the cameras, this option was not only costly but also equally difficult to process as our site perimeter was about 60 meters. The third option is to rely on a structure similar to a drying rack to fix the camera. The third option was adopted due to its low material cost and low processing difficulty.
The main equation for designing the installation is the equation of balance

$$\sum \vec{F} = 0 \tag{4}$$

$$\sum \vec{M}_O = 0 \tag{5}$$

Where $\vec{F}$ is the force applied to the objective, $\vec{M}$ is the moment applied to the objective. Considering that the soil modeling requires at least two pictures for which the camera keeps still at 0 degrees and 180 degrees to take photos, we connect a servo at the bottom of the camera and use a PCB to control the behavior of the motor. The PCB could give a 0.5ms pulse and a 2.5ms pulse to use the PWM signal to let the servo rotate to 0 degrees and 180 degrees.

2.2.2 Design details

Control Module: The control module includes a power control button and status LEDs and is charged by the storage battery. The power control button is used to control whether we need to let the sensors work, and the LEDs show the working condition of the whole system.

Sensor Module: The sensor module includes the temperature transducer and the humidity transducer. This part relates to the storage battery to make sure it can work properly, and the soil to test the temperature and humidity of our experimental subject. These sensors are respectively buried 1, 3, 5, 10, and 15 centimeters beneath the soil to get hierarchical data of the soil. The sensors could upload the value of the resistance and the dielectric of the soil and use the equations mentioned in the Design Procedure to calculate the temperature and humidity of the soil.

Data Storage Module: The data storage module includes the data storage unit and the data preprocessing unit. The storage battery is connected to this part to give a power supply, and the output of the sensor module flows to the data storage module for further operation. The data storage unit is used to store all the information we collected in the sensor module, and the function of the data preprocessing unit is to calculate the resistance of the soil through the value of the current sent by the sensors to get the dielectric constant of the soil and ulteriorly, the temperature and the humidity of the soil.

Camera Module: The camera module contains the power and its control button, the camera, the PCB, and the servo. We use a switchable battery holder that contains six batteries of 1.5 volts each to supply the power of the PCB and the servo. The reason why we chose 9V as our power supply is that the working voltage of the servo is 4.8V and 6V, and the resistance of the PCB is huge. Lower voltage will not drive the servo. The battery holder is connected to the Vin and G pins of the PCB.

We can add two types of programs onto the PCB to control the behavior of the servo.
The first program is to let the camera graduate move from 0 degrees to 180 degrees and back, repeat this procedure so that the camera can work without any blind spots. This program lets the servo move 1 degree per 15ms. We use "pos" to record the angle the servo moves, and once it reaches 180 degrees, "pos" will decrease, and the servo will move from 180 degrees to 0 degrees and then start a new loop.
The second program serves for soil modeling. We can use this program to let the camera rotate and keep still at 0 degrees and 180 degrees to take the photos we need in soil modeling. The program gives a PWM signal for PWM control. At time 0, it will give a 0.5 ms pulse that will cause the servo to recover to the original state, whose angle is 0. Then it

will give a 20-second delay, which should be 1 minute in actual use, to allow the user to press the screenshot button on our online portal. After the 20-second delay, it will give a 2.5-ms pulse to let the servo rotate to 180 degrees and stay there for 40 seconds, which should be 10 minutes in actual use. In this position, the user can press the screenshot button and get another picture that we use in our soil modeling. When the entire loop is completed, the servo will reset and start a new cycle.
The servo is connected to the PCB with 3 wires. The signal wire is connected to pin 16 of the PCB as the input of our code. The other two wires are connected to the positive pole and the GND of the PCB separately so that we can use the PCB to control our servo.
For the rotating camera, we used a rotating system to connect it to the servo. The system consists of several frames, one D-shape rod, and a pair of gears, which are shown below.

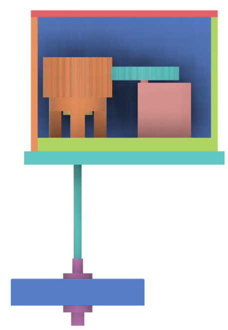


Figure 3: Schematic of the rotating system

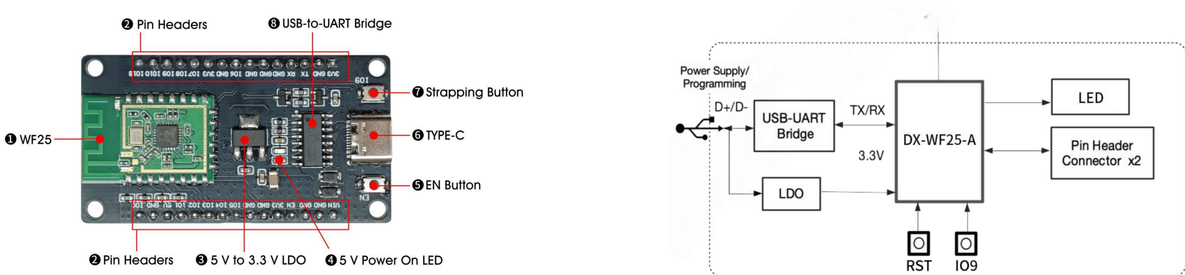
The specification of the flange is 22mm OD and 6mm ID with 4 3mm diameter light holes attached. The D-shaped rod has a diameter of 6mm. Detailed engineering drawings with other parameters will be attached in the appendix.
Before the prototype, we measured some parameters and substituted them into the balance equation to calculate its feasibility. The following is the general feasibility proof process.

Wireless Information Transform Module: The wireless information transfer module contains three parts: SIM card 1, SIM card 2, and the cellular network. SIM card 1 is connected to the data storage unit to transfer the data to the cellular network, and SIM card 2 relates to the camera to upload the graph to the cellular network. The cellular network will then upload all the soil data and camera photos to the online portal.

$$
\begin{aligned}
F &= \frac{T}{KD} = \frac{0.5\,\mathrm{N\,m}}{0.2 \times 0.003\,\mathrm{m}} \approx 833.33\,\mathrm{N} \\
f &= \mu F = 0.15 \times 833.33\,\mathrm{N} \approx 125\,\mathrm{N} \\
&\quad\quad (\text{Since } 125\,\mathrm{N} > 20\,\mathrm{N} \Rightarrow \text{D-shape rod works})
\end{aligned}
$$

$$
\begin{aligned}
\text{Torque}_{\text{load}} &= 25\,\mathrm{N} \times 5\,\mathrm{cm} \times 0.4 = 0.5\,\mathrm{N\,m} \\
&= 5\,\text{kgcm} \quad (\text{Since } 5\,\text{kgcm} < 20\,\text{kgcm} \Rightarrow \text{Servo works})
\end{aligned}
$$

2.2.3 Diagrams and Schematics



(a) PCB schematic

(b) PCB theorem

Figure 4: PCB design diagrams

2.3 Online Portal

2.3.1 Design procedure

The Online Portal Subsystem is the user interface for our system, providing access to real-time and historical environmental data, camera images, visualization results, Tolerance, and analysis results. It includes a sensor module, a data processing module, a visualizing module, and an online portal.

The online portal enables remote monitoring and analysis of the soil and environmental conditions. It improves the user's insight into soil environment changes, helps users make quick judgments, and makes the system data more intuitive and understandable through visual reports and graphical interfaces. It also facilitates informed decision-making for agricultural management and research through data analysis and AI models.

2.3.2 Design details

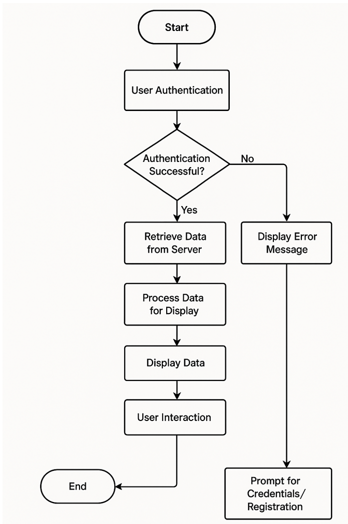
Sensor Module: The sensor module's server receives all data from the wireless information transfer module, including numerical sensor data, images, and videos. It can classify data and store it in a SQLite database to support historical data queries and statistics. The sensor module (i.e., the server) provides APIs, links, and other interfaces for other modules to call, while also accepting data from the remote detection system. As the back-end of the system, it is implemented using Flask, a Python backend framework, to support user access and data storage.

Data Processing Module: The data processing module deeply processes and analyzes the environmental data from the server of the sensor module. The average daily temperature and humidity, soil moisture distribution, and soil temperature distribution maps are calculated. Moreover, two estimation models for processing the images taken from the camera to get the soil surface flatness are utilized to predict real-time soil surface conditions. There are many implementation algorithms for analyzing the soil surface, such as the method using two synchronized images to create a continuous 3D polygonal surface from a 3D point cloud [4]. Also, it's possible to use the fractal analysis on digital images of the soil surface to get the soil surface flatness parameter [5]. In practice, we use 3 algorithms to get the modeling result, including binocular vision modeling and monocular vision modeling using depth estimation algorithms like Depth-Anything [6].

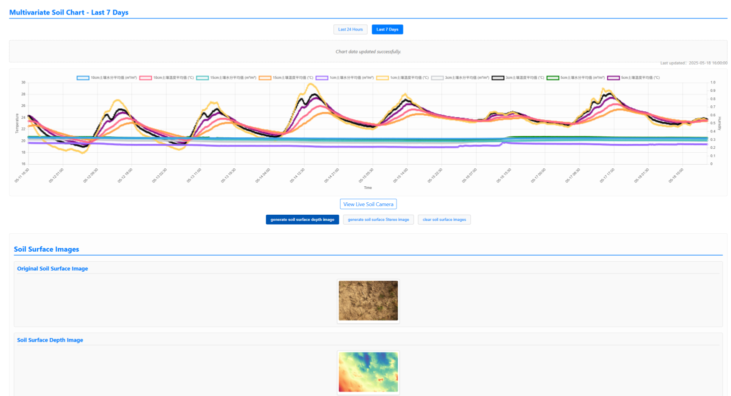
Visualizing Module: The visualizing module generates various visual charts and graphs(line chart, bar chart, heat map, etc.), like the soil humidity and temperature trend curve, in a user-friendly format. The graphical representation of sensor data is easy for users to feel and check intuitively and quickly. It also provides links to view the camera images and videos. Also, it will show the results and corresponding files for the soil surface modeling. There are several algorithms for estimating the model, so there will be several options on the online portal. The analysis results (processed data) and visualization results (visualized data) from the data processing and visualizing modules are fed back to the server for storage and pushed to the Online Portal to display.

Online Portal: The online portal provides a web-based access interface where users who have been authenticated can view real data, historical trends, camera images, and video streams through a web browser. It connects closely with the data processing and visualizing modules to get the latest data, charts, and camera images and render them on the front page. The system allows users to remotely monitor site conditions and access past soil data over the network.

2.3.3 Diagrams and Schematics



(a) Flowchart for Online Portal Access



(b) Website Display

Figure 5: Online Portal: (a) Flowchart and (b) Website Interface

3 Requirements and Verification

3.1 Power Supply

Requirement	Verification
The solar panel must provide sufficient power to charge the battery under the average sunlight conditions on the ZJUI campus.	Measure the solar panel's output and input power under various sunlight conditions, it should have a higher producing power than input power.
The regulator must regulate the voltage of the rechargeable battery to the required working voltage of our devices (sensors and cameras)	Measure the current and voltage after regulating, it should be around 12 V

3.2 Data Collect

Requirement	Verification
The solar power should supply enough energy to the sensor and the supporting system to make sure that they can work 24 hours per day	check the online portal to see if we can have the data every 15 minutes.
The control button should work immediately, and the status LEDs should reflect the correct status.	Press the button and check on the online portal to see if the system still works and check the status LEDs at the meanwhile.
The sensors should give correct temperature and humidity to the wireless transform module	Set a thermometer and a hygrometer under the soil and compare them with the data we get from the sensor
The rotation system needs to rotate the camera without dropping it. Tolerance: 12 days (3 days) when no wind, 3 days(2 days) when windy	Placing the system outdoors for extended periods of time, if necessary considered to create small vibrations to simulate high wind conditions. Stored in the wild for 3 days with no drops, barely meets our requirements, but still needs to continue testing
In mode 1, the camera should be able to go to angle 0 at time 0 and wait for 20 seconds. Then it should move to 180 degrees, keep still for 40 seconds, and then start a new loop.	Set a clock to record the time and use a protractor to observe the behavior of the camera.
In mode 2, the camera should be able to graduate move from 0 degrees to 180 degrees and from 180 degrees to 0 degreescomparison and repeat this procedure	Set a protractor to observe the behavior of the camera.

3.3 Online Portal

Requirement	Verification
The portal must display sensor data in a clear and understandable format.	Access the portal and verify that the sensor data is displayed correctly in the charts and graphs.
The portal must provide access to the captured camera images.	Access the portal and verify that the camera images are displayed correctly.
The portal must implement the Soil Flatness AI Model and display its output.	Access the portal and check the performance of the Soil Flatness AI Model by comparing the output result of the AI model with the soil flatness measured by the traditional Straightedge and Feeler Gauge Method.
The portal must be accessible through a web browser on various devices (computers, mobiles).	Access the portal with different web browsers and devices to test its compatibility.
The portal should have a user authentication mechanism.	Access portal with authorized and unauthorized usernames to test the user authentication mechanism.

3.4 Tolerance Analysis

For the sensors, the tested temperature and humidity at 5 p.m. The 13 April is 20.900 (1 cm), 0.298 (1 cm), 20.000 (3 cm), 0.335 (3 cm), 20.000 (5 cm), 0.359 (5 cm) while the data we collected using thermometer and hygrometer is 20.1 (1 cm), 0.291 (1 cm), 19.8 (3 cm), 0.328 (3 cm), 19.7 (5 cm), 0.361 (5 cm). The error is relatively small compared to the data itself and is within our acceptable range.

For the estimation of soil flatness, there will be errors between the estimated value and the real one. We will evaluate the soil flatness through algorithm using images, which will have some error and we get the real value using the pin meter **??** [7], which will have tolerance in the measuring part since the soil is soft and the pin meter has intervals among the pins. There are also errors when we measure the length of the outline with the algorithm.

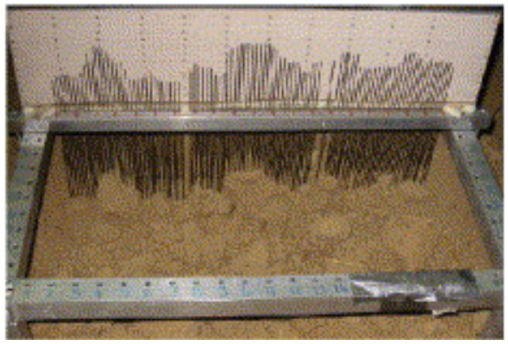


Figure 6: Pin Meter

4 Cost Analysis

Table 4: Estimated Average Labor Cost for Each Team Member

Name	Hourly Rate (RMB)	Hours	Sub-total (RMB)
Member 1	20	280	5600
Member 2	20	280	5600
Member 3	20	280	5600
Member 4	20	280	5600
Total		1120	22400

Table 5: Total Bill of Cost

Part	**Item**	**Quantity**	**Cost [RMB]**
Data Collect	Cabinet	1	1350
Data Collect & Power Supply	HYKVISION Camera	1	429
Data Collect	Connectors (includes Fran, screw)	N/A	12
Data Collect & Power Supply	Sensors, Bracket, Solar Panel and Battery	1	23750
Data Collect	3D Printing Material	150g	25
Data Collect	esp8266 nodmcu	1	25.72
Data Collect	Servo	1	34
Data Collect	Stainless Steel Board	50*30	90
Data Collect	D-shape Rods	1	6
Data Collect	Orbbec Depth Camera Astra Pro Plus	1	950
Data Collect	Acrylic Board	2	65
Data Collect	String	1	2.6
All Parts	Labor Costs	N/A	22400
TOTAL			49,139.32[1]

[1]Most devices are provided by Prof. Tan's Lab

5 Schedule

Table 6: Project Team Weekly Work Log 1

Week	X. Wu	Y. Chen	C. Chen	D. Dai
week1	Initial background research; literature survey.	Market research: ID existing systems.	Project scope definition; background study.	Soil sensor tech; basic principles.
week 2	Case studies: Analyze successful systems.	Market research: Competitor analysis.	Tech investigation (sensors, comms).	Literature review: Data acq., transmission.
week3	Study soil sensor manuals; specs	Local test prep: Sensor env. setup.	Study equipment. install guides.	Camera/servo manuals; functions.
week4	Data logger/module manual; integration plan.	Local functional test: Sensor data/accuracy.	Outdoor install stds; weatherproofing.	Soil flatness methods research.
week5	(Collab) Sensor assembly; initial bracket design.	(Collab) Site prep; assist bracket foundation.	(Collab) Lead bracket install; stability.	(Collab) Sensor positioning; cable mgmt.
week6	(Collab) Finalize bracket; initial sensor tests.	(Collab) On-site sensor install; bracket fix.	(Collab) Waterproof sensor interfaces.	(Collab) Initial sensor calibration; stability check.
week7	Read camera manual; power/data plan; fixture design.	Flask setup; backend API design.	Camera network config; LAN test.	Soil flatness definition; algorithm research.

Table 7: Project Team Weekly Work Log 2

Week	**X. Wu**	**Y. Chen**	**C. Chen**	**D. Dai**
week8	Finalize camera fixture; procure parts.	Website front-end layout; data display frame.	Remote camera access debug.	Eval. flatness methods; short-list algorithms.
week9	System work-flow design; data interaction.	Real-time data display dev (charts).	Power distrib. box install; line org.	Design a code flatness algorithm.
week10	Optimize system coordination; stability.	Integrate data stream to front-end.	Servo install	config; basic tests. Test the flatness algorithm; compare with manual.
week11	(Collab) hardware assembly; prelim. integration test.	Website user auth.	security.	(Collab) Mount the camera to the servo. Integrate flatness results into the backend.
week12	(Collab) Full system debug; Reproduce the rotate system for better performance	verification.	Optimize website UX; compatibility test.	(Collab) Servo control program dev. Test algorithm w/ soil samples; optimize.
week13	(Collab) Prep final demo materials; rehearsals. Reproduce the rotate system for better performance	finalize website test	deploy; docs.	(Collab) Fine-tune camera/servo; final integ. Display flatness on the website; compare.
week14	(Collab) Prep final presentation and report	(Collab) Prep final presentation and report	(Collab) Prep final presentation and report	(Collab) Prep final presentation and report

6 Conclusion

6.1 Accomplishments

This project successfully developed and implemented a Remote Environment Recording System with Online Access Portals, achieving all core objectives outlined. Key accomplishments include the integration of multi-depth sensors for real-time soil temperature and humidity collection, coupled with a camera system capable of both general site surveillance and capturing images for soil surface modeling. The entire field system demonstrated sustainable operation through its solar power supply. Furthermore, all collected data, including sensor readings and camera imagery, is wirelessly transmitted and made accessible via a user-friendly online portal. This portal not only displays raw and processed data through dynamic charts and analyses but also features a novel soil surface modeling function. Our system effectively provides a robust solution for enhanced agricultural monitoring and environmental research.

6.2 Uncertainties

Some features didn't live up to our expectations. The first is the integration of the PCB's functionality. To serve soil modeling, we eliminated the study of remote manipulation, which would have been nice if we could have done both remote manipulation and soil modeling at the same time.

The second is the stability test of the clamping system, which has not been able to last for more than one week and still carries the risk of instability.

The third is that the communication module of the camera is greatly affected by the signal, and the fact that it can be used in the test site does not mean that it will be used in the large farms after commercialization.

The fourth was that we realized that the camera's center of gravity was so far out that we couldn't stabilize the camera by placing it vertically downward until our project was in post-production. To solve this problem, we used a rope to tie it down, which worked well, but we still hope it can be improved.

6.3 Future Work

For our future work, we can conduct a detailed cost-benefit analysis and accelerated environmental testing (temperature cycling, immersion, UV exposure) on prototype enclosures and battery modules to validate long-term field performance. Also, we can replace the support string used for the monitor mode changing. We can add a PCB control board with a servo and gears to make the camera lift and fall. For the soil surface modeling work, we can try more AI models and test their accuracy. Building or finding a dataset of soil surface photos and the depth data, and then using it to fine-tune the depth estimation AI model, might improve the existing model's performance on soil surface modeling.

6.4 Ethics and Safety Consideration

As an engineering group, we should have a clear and strict code of ethics. To this end, building on the IEEE Code of Ethics [8], we have decided to highlight or add the following code of ethics.

6.4.1 Privacy Protection

We should ensure that cameras and sensors collect only soil-related data and do not record personal activities or other sensitive information, and approvals from landowners should be obtained before monitoring. We must protect our collected data when transforming and storing it, ensuring security, for example, by processing locations and images to hide important information.

6.4.2 Data Transparency

We will clearly define data ownership and usage scope, detailing the purpose and retention period for each dataset and informing our supervisors. We strictly prohibit data exploitation for commercial gain, political manipulation, or non-scientific purposes.

6.4.3 Sustainable Practices

We will prioritize low-energy, recyclable hardware to minimize waste and regularly assess ecological impacts, such as soil disruption, implementing mitigation measures as needed.

6.4.4 Risk Disclosure

If we detect possible soil contamination or other environmental problems, we will immediately suspend the project, notify relevant authorities, and provide data proof.

6.4.5 Technical Reliability

We will check and maintain equipment regularly to ensure sensors are installed according to industry standards and inform users promptly when system issues arise.

6.4.6 Conflict of Interest Avoidance

We will prohibit impartiality errors caused by accepting bribes, use only budget funds allocated by the school, and report promptly if expenditures exceed the budget.

6.4.7 Inclusive Design

Our system design will account for regional variations, such as device assembly and power supply availability, and prepare countermeasures for different environments.

6.4.8 Team Accountability

Team members must adhere strictly to contractual commitments, participate earnestly in project work, and admit and remedy mistakes promptly.

6.4.9 Regulatory Adherence

We will ensure compliance with local privacy laws, environmental regulations, and land-management policies during data collection, transmission, and storage.

6.4.10 Electrical Safety

The switch must remain off until the circuit is confirmed to work properly to avoid electric shock, and anyone operating under high voltage must first undergo dedicated training.

6.4.11 Mechanical Safety

When assembling or maintaining equipment—using tools such as shovels—team members must take care to avoid cuts, falls, sprains, and other injuries. When machining support parts (e.g., welding or cutting), at least two people, including the lab manager, must supervise to prevent serious accidents.

6.4.12 Lab Safety

All personnel must complete mandatory online safety training and submit completion certificates on Blackboard before working in the lab. Equipment manuals containing chemical handling instructions must be read carefully and followed, and appropriate protective gear must be worn during laboratory work to minimize accident risk.

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Appendix A Example Appendix

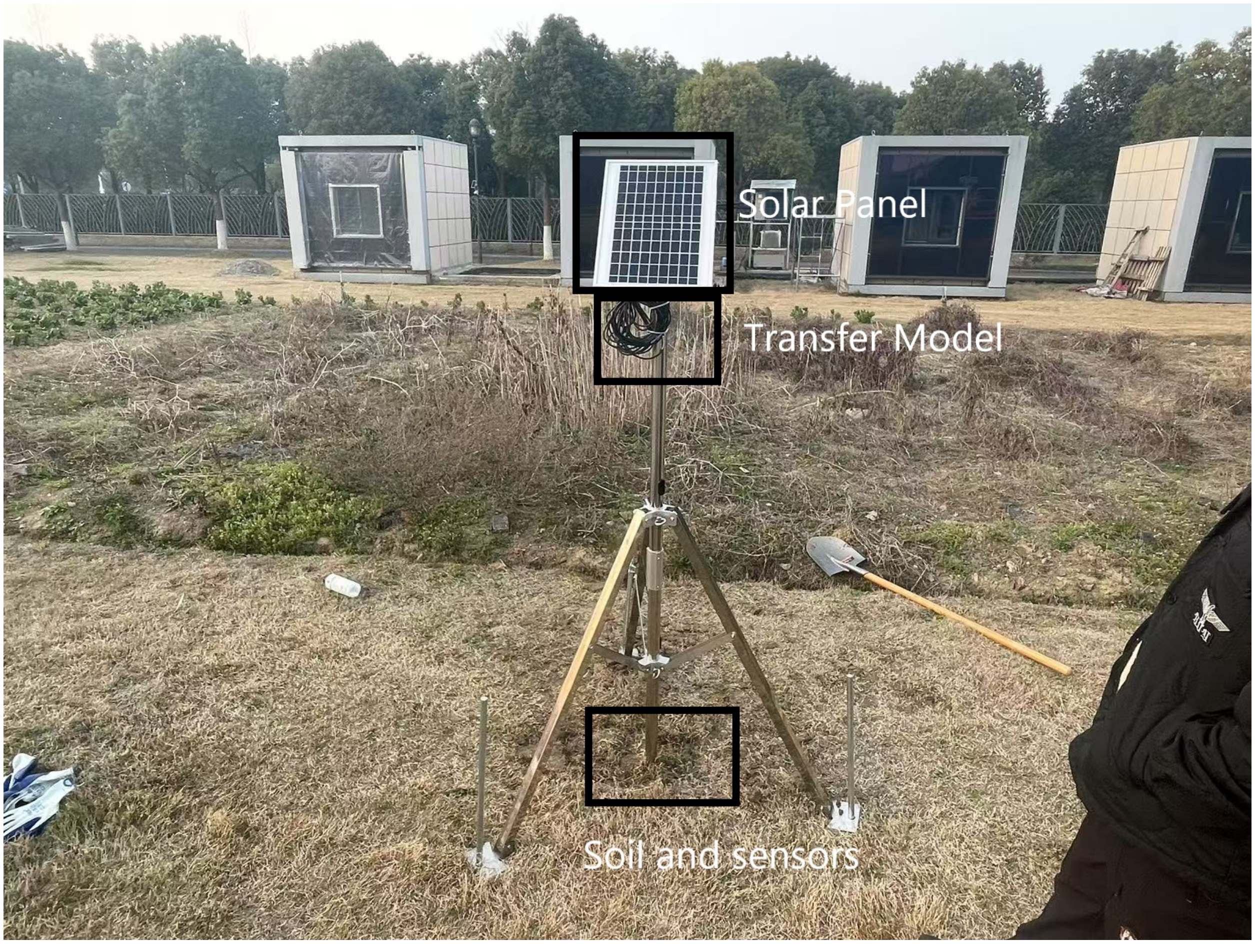

Figure 7: System Overview

Figure 8: Sensors Overview

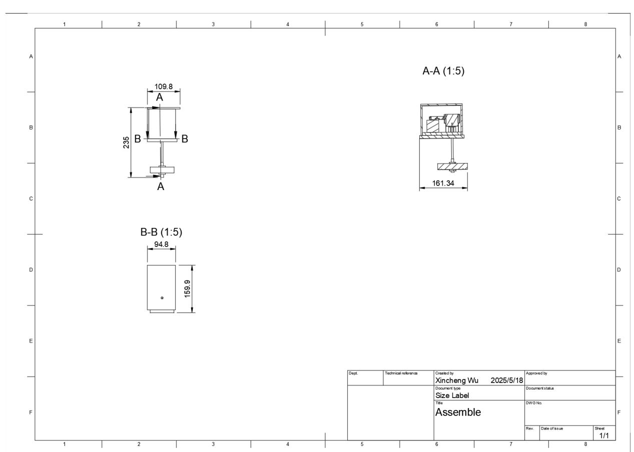

Figure 9: Assemble with size