ECE 445

SENIOR DESIGN LABORATORY

PROPOSAL

PROPOSAL: A Remote Environment Recording System With Online Access Portals

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Team #17

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1 Introduction

1.1 Objective and Background

1.1.1 Goals

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. Inappropriate environmental factors are harmful to the agriculture. For instance, unsuitable temperatures inhibit plant growth and reduce cell viability; Unsuitable humidity affects root growth and leads to malnutrition. 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 often depend on non-renewable power sources. Additionally, they provide only static measurements rather than an interactive digital representation and analysis of environmental changes. Therefore, we want to optimize the versatility of physical detection equipment and build a remote monitoring platform with digital twin modeling.

1.1.2 Functions

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 the information on the humidity, temperature, and the surface roughness of soil; setting up a camera to supervise in real time; uploading all the data to the website platform; and visualizing it.

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 degression 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, in industrial production, this may help the controller to 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.

1.1.3 Benefits

1. The system enables remote and real-time soil and environmental monitoring for farmers and researchers.
2. The system improves decision-making for irrigation and crop management through predictive insights from the digital twin.
3. The system provides a sustainable and low-maintenance monitoring solution through solar power.

1.1.4 Features

1. Self-sustained power using solar energy, eliminating external power dependency.
2. Multi-depth sensing, offering more accurate insights into soil conditions.
3. Real-time camera feed, enhancing situational awareness.
4. Wireless data transmission, reducing the need for physical access.
5. User-friendly web portal and visualization, making data easily accessible and interpretable.
6. Digital twin modeling, allowing historical trend analysis and predictive modeling.

1.2 High-level requirements list

1. 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).
2. The camera must provide real-time ground condition monitoring (≤ 1 min latency on the web portal).
3. The web portal should provide the access to data from the sensor and camera, with visualization and a digital twin modeling.
4. The entire system should be able to run normally on solar energy through a 10W $\times$ 2 solar panel, ensuring continuous operation under variable weather conditions.

2 Design and Requirement

2.1 Block Diagram

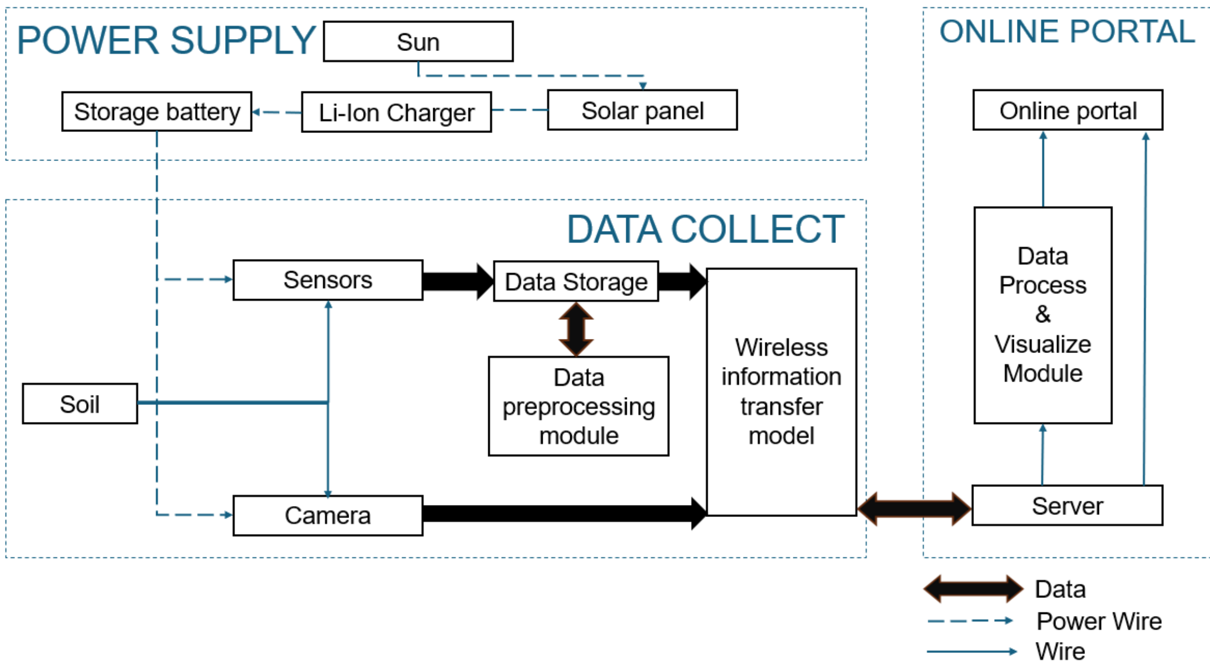

Figure 1: Block Diagram

2.2 Block Description

2.2.1 Sun & Solar Panel

The photovoltaic effect is used in the device to convert solar energy into electricity, providing the main energy source for the remote environmetn detecting system. This module helps the sensors work continuously in areas away from mains or electricity instability remotely. The output is connected to the Li-Ion Charger through a cable, and the converted DC energy is sent to the charger for voltage regulation and charge management. It makes the system capable of sustainable and green energy supply, especially for the remote environment detecting system, which is hard to be powered by the outer power network.

2.2.2 Li-Ion Charger

It receives the power from the solar panel, and carry out protection measures such as voltage regulation and current limiting to ensure the safe and efficient charging of the energy storage battery. Its input will be connected to the solar panel to receive its output direct current. Output will be connected to the Storage battery and provides power to the battery. It can extend the life of the energy storage battery to avoid excessive loss or safety hazards during charging, which help with the steady of system.

2.2.3 Storage Battery

It stores the electricity provided by solar panels and chargers to provide continuous power to the system at night or in rainy weather when enough solar energy is not available, satisfying the needs of sensors, cameras and data transmission modules. It is associated with a lithium battery charger, accepts charging, and supplies power to each power module. And through the voltage control module to adjust the output voltage to the appropriate range, supply to the subsequent components. It provide continuous, stable power for the data collecting module in the system.

2.2.4 Soil

Soil is the observation object in our senior design project lab. To make our lab fits the practical application in the daily life and the commercial utilization, we choose the experimental site randomly in the farmland in our campus. The temperature and the precipitation is normal and can furthest represent the average of the whole area of Zhejiang province. To test the temperature, humidity and the flatness of the soil, we will need to use the sensor and the camera to detect the data and record them.

2.2.5 Sensors

Sensors are used to detect the temperature and the humidity of the soil. In order to make data visualization and have a comprehensive command of the whole soil to see the variation, the depth of the measurement is defined at 1 centimeter, 3 centimeters, 5 centimeters, 10 centimeters and 15 centimeters. To make the data more accurate, we decided to dig out a cylindrical hole that heights 20 centimeters, which should a bit deeper than the maximum depth we try to measure (15 centimeters). Also, the 5 sensors should gather as close as possible to avoid the differences of the soil in various regions. For each sensor, there are 3 wires that needed to be connected. The voltage wire, which allow the sensor to work. The GND wire, which is in pairs of the voltage wire. The signal transmission port, which sends all the information it collects to the coupler. After the collection of the data, the sensors will transfer all of the information to the coupler.

The coupler is connected to the 5 sensors and the solar power supply. The solar power supply supports the coupler to work 24 hours per day as the consumption of the power is much less than the energy given by the power supply in average after calculation. The sensors are connected to the coupler by 5 ports. In each port, there are 3 wires needed to be connected between the sensors and the coupler, the voltage port, the GND and the signal transmission port. The wireless information transfer model is connected with the coupler. The function of the wireless information transfer model is to store the data collected by the sensors every 15 minutes and upload all of the information to the network per hour. In addition, there is an update button on the surface of wireless information transfer model and by pushing this button, all the information collected in this procedure can be updated to the network immediately to let the observer know the real time data in this field. In this way, we can know how the variables changes as the time and depth changes. This system makes the data more intuitionistic and is helpful for the step of data visualization.

2.2.6 Coupler and Wireless information transfer model:

The camera is used to record the environment of the experiment field and the flatness of the soil. The camera can update the real time picture of the environment to the network so that the observers can become conscious of the field any time they want. In addition, by comparing the photos of the camera and the standard features of the flatness, we can roughly find out the flatness of the field we observed. In this way, we can find out information about the flatness of the whole filed and figure out whether there is any relationship between the flatness and the temperature and the humidity. We want the camera to be charged by the solar power system, but it is a bit challenging since the camera is fabricated by other merchants and we are not familiar with the structure. Also, the solar power supply may be not enough to support the camera to work properly. As this result, we list this draft resolution to our tolerance solution. If there is still enough time after we finish all the other things, we will try to figure out this problem.

2.2.7 Camera

All the data in this experiment is collected by the sensors and the camera initially and will be stored in the coupler. After every 1 hour, the Wireless information transfer model may send all of the information to the network for the sever to make further analysis. If all the requirements are met, the led light of the coupler should be red, which means there is enough power for the whole facility to work. There should be information of the temperature and humidity of every 15 minutes on our website. Also, after pushing the update button on the wireless information transfer model, we should see that there is new data presented on the website. For the camera, it should be accessed on the website, and we can see the real time picture of the experiment field. The whole system should be able to work 24 hours per day if the solar power system fits our requirement.

2.2.8 Server

It receives and integrates all data transmitted wirelessly from the front end, including sensor data, images and video. It can classify data and store it to support historical data query and statistics. The server can provide apis and other interfaces for other modules to call, while also accepting data from the remote detecting system. As the back-end of the system, it supports multi-user access, data processing and storage.

2.2.9 Data process & visualize module

The environmental data received by the server is deeply processed and statistically analyzed, and the average daily temperature and humidity, soil moisture distribution, soil temperature distribution map, and humidity and temperature trend curve with time and date are calculated. Generate a variety of visual charts (line chart, bar chart, heat map, etc.), easy for users to feel and check intuitively and quickly. Get data from the server; The analysis and visualization results are fed back to the server for storage and pushed to the Online Portal. 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.

2.2.10 Online Portal

It provides a web-based access interface where users can view live data, historical data, camera images and video streams. It connects closely with the server and the "Data process & visualize module" module to get the latest data, charts, and surveillance videos and render them on the front page. In the system, it allows users to remotely monitor site conditions and access past soil data over the network at any time.

2.3 Risk Analysis

For the Wireless information transfer model, we decided to build our own receiving and transmitting device based on the basics of Raspberry pie. We list this procedure in our risk analysis due to the following reasons: 1. The collector software may not be compatible with the hardware; 2. It is hard to use the solar power supply to support the work of our Wireless information transfer model since it may cost more energy to work; 3. The space may be not enough for us to set the Wireless information transfer model since the fixator does not have enough space; 4. The compilation of wireless module is rather difficult. For this reason, if our try of building the Wireless information transfer model fails, we may use the Wireless information transfer model that which has been developed to accomplish our lab.

3 Ethics and Safety

3.1 Ethics

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

3.1.1 Privacy Protection

- We should ensure that cameras and sensors collect only soil-related data. We should not record personal activities or other sensitive information. Also, approvals from landowners should be obtained before we start to monitor.
- Protect our collected data, when we are trying to transform and store them, make sure they are secure. For example, the locations and images should be processed to hide important information.

3.1.2 Data Transparency

- Clearly define data ownership and usage scope. For every group of data, we describe in detail our purposes and the retention periods of the data. Also inform our supervisors.
- Prohibit strictly data exploitation for commercial gain, political manipulation, or nonscientific purposes.

3.1.3 Sustainable Practices

- If we can, use low-energy recyclable hardware firstly to minimize waste.
- Regularly assess ecological impacts, for example, the soil disruption. And implement mitigation measures.

3.1.4 Risk Disclosure

- When we find possible soil contamination or other environmental problems, we immediately suspend the project, notify the relevant authorities and provide data proof.

3.1.5 Technical Reliability

- Check and maintain equipment regularly to ensure that sensors are set up in accordance with industry standards. Inform users clearly and quickly when there are problems with the system.

3.1.6 Conflict of Interest Avoidance

- We will strictly prohibit impartiality errors caused by accepting bribes, use only the budget funds allocated by the school, and report timely when the budget is exceeded.

3.1.7 Inclusive Design

- System design needs to take into account the characteristics of different regions, such as the assembly of the device, whether the supply of power systems is adequate. Prepare countermeasures for various environments

3.1.8 Team Accountability

- Team members need to strictly abide by the content of the contract, seriously participate in the work of the project, and promptly admit mistakes and compensate when they make mistakes.

3.1.9 Regulatory Adherence

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

3.2 Safety

In order to protect the safety of students and users, we also need to follow safety rules and avoid risks.

3.2.1 Electrical safety

- The switch must be kept off until the circuit is confirmed to work properly to avoid electric shock.
- In the case of high operating voltage, you must first undergo high voltage environment training before you can operate.

3.2.2 Mechanical safety

- When assembling and checking maintenance equipment, due to the need to use tools such as shovels to work on the land, you need to be careful of cuts, falls, sprains and other physical injuries.
- Machining equipment such as welding and cutting may be used when processing the support parts of the equipment, and at least 2 people, including the laboratory manager, must supervise the use of these equipment to avoid unremediable accidents.

3.2.3 Lab safety

- Everyone must complete a mandatory online safety training in order to be allowed to work in the lab. Certificates of completion must submitted on Blackboard.
- Read the instruction manual carefully before using the equipment containing chemical substances and follow its instructions.
- Complete equipment must be worn when performing laboratory work to minimize the possibility of accidents.

Appendix A Example Appendix

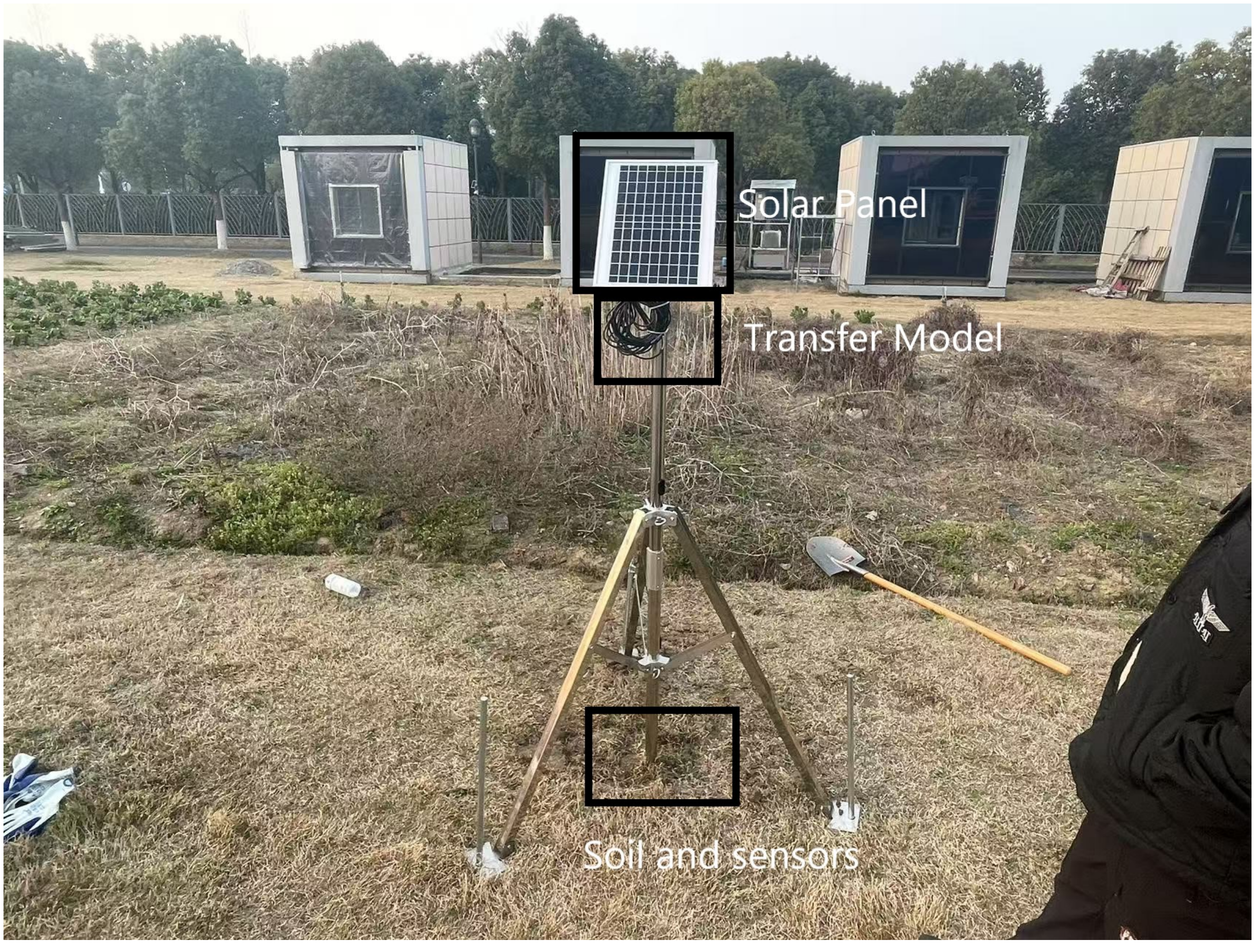

Figure 2: System Overview

Figure 3: Sensors Overview