Person-Portable Soil Moisture Mapping System

Abiel Tewolde, Brandon Little, Calvin Ulsh, Spencer Jones, Wenqian Xu, Zhixian Jin
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OMEGA

Objectives

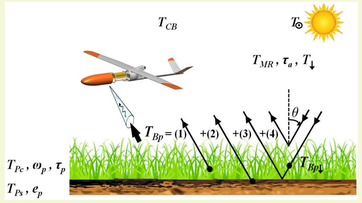
The Person-Portable Soil Moisture Mapping System is an alternative to unmanned aerial, or satellite systems of similar technology. It's higher resolution design can be more useful for surface mapping validation, precision agriculture, evaporation and transpiration studies of boundary layer heat transport. The more affordable Person-Portable Soil Moisture Mapping System allows users such as researchers, landowners and farmers to map their land for **Volumetric Soil Moisture (VSM)**, **Normalized Difference Vegetation Index (NDVI)**, and thermal temperature in real time.

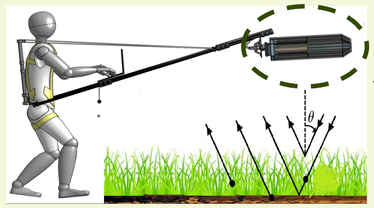
Unmanned Aerial/Satellite Design

- Decameter Resolution
- NDWI (NIR, SWIR Wavelength)
- Not Real-Time

Person-Portable Design

- Meter Resolution
- NDVI (Red, NIR & Green Wavelength)
- Real-Time





Introduction

The Person-Portable Soil Moisture Mapping System is a product that can help users to determine the soil moisture saturation in a range from **2-3 square meters** at one time. Users can carry the product and walk around to determine the large scale of soil moisture saturation and map it for **2.5 hours**. The product uses optical sensors to determine NDVI and uses **Lobe Difference Correlation Radiometer (LDCR)** to measure the microwave. The user interface **Raspberry Pi (Raspi 400)** takes two inputs (NDVI and microwave) and determines the soil moisture saturation. Then the Raspi 400 will combine GPS data and soil moisture saturation data and map the real-time soil moisture saturation.

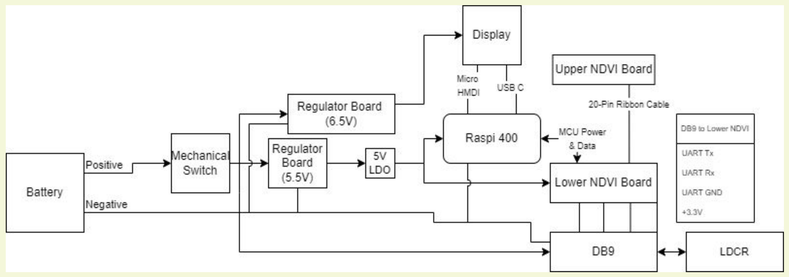


Figure 1: Brief System Schematic

Acknowledgement

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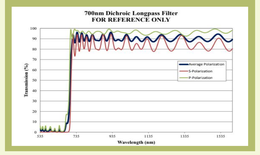
Figure 6: Raspi 400 Computer with 7-in LCD display

Sub-Systems

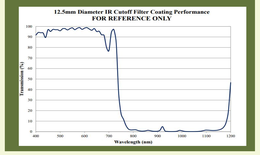
Normalized Differential Vegetation Index Sensor (NDVI)

VSM is known to be correlated with vegetation indices such as NDVI and **Normalized Differential Water Index (NDWI)**. The unmanned aerial system designed by the CET lab uses NDWI to calculate the soil moisture, whereas the Person-Portable Soil Moisture Mapping System uses **NDVI** and extra **GREEN** wavelength to improve accuracy over previous methods.

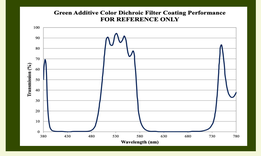
IR Cut Off Filter
Filter Out Red Wavelength
Edmund Optics #55-234
λ 635~700 nm

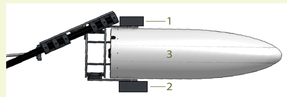


Longpass Filter
Filter Out NIR Wavelength
Edmund Optics #69-870
λ 750~1400 nm



Green Filter
Pass Green Wavelength
Edmund Optics #52-533
λ 450~580 nm





1. Upper Optical Sensing Board
2. Lower Optical Sensing Board
3. Upper & Lower LDCR Boards Contained in the LDCR Chassis

Figure 2: Positions of 3 Boards

To get rid of the effect of **ambient radiation**, one sensing board faces up which the majority of its measurement is ambient radiation. The other facing down board is measuring the ambient radiation and radiation reflected back from ground. By measuring both two kinds of radiation and applying our algorithm, the ambient radiation can be filtered out.

Optical sensor (OPT301) is a photodiode which will change the voltage across it according to the light intensity hit on it connected to an amplifier. According to the figure 3, the ratio of voltage across the photodiode and the power of light with different wavelengths hit on the photodiode.

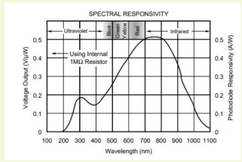


Figure 3: OPT 301 Spectral Responsivity

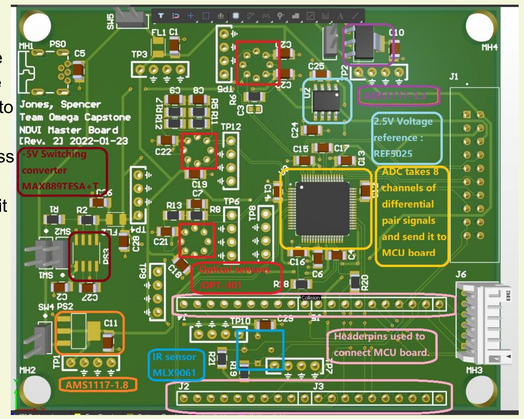


Figure 4: NDVI Board

Lobe Difference Correlation Radiometer (LDCR) Sensor

The Lobe Difference Correlation Radiometer is provided by **Blackswift Technology**, This component generates a value based on the microwave radiation reflected from the surface being measured. It is configured to output over UART by the company.

Position Acquisition

The **ZED-F9P module** from u-blox is a multi-band GNSS receiver providing **decimeter** accuracy, and can be pre configured using ublox u-center application. The position data will be sent to the Raspi 400.

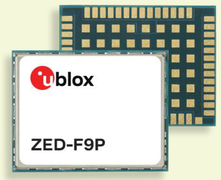


Figure 4: ZED-F9P Breakout

Raspi 400 Personal Computer

Raspi 400 personal computer is equipped with a 7-in LCD display, performing the bulk of calculations and mapping. The raw NDVI, LDCR, thermal sensor data is sent to the Raspi 400. Then Raw Data, Thermal Map, and VSM Map are displayed. The user can check the feasibility of the soil moisture mapping system by raw data, and adjust the moving trajectory by real-time thermal and VSM map.

Mechanical Structure

Requirements:

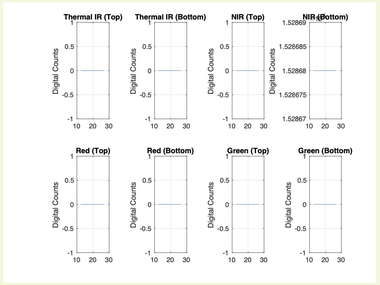
- Suspend sensors seven feet out in front of the user at eye level
- Lightweight and comfortable to wear
- Balanced, with an equivalent forward and backward moment

Design:

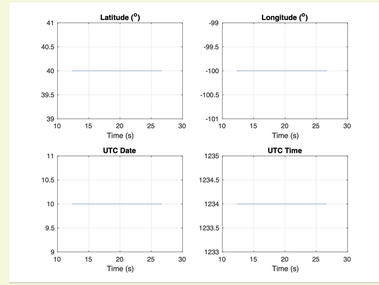
- **Frame**
  - Child Carrier Hiking Backpack designed to be ergonomic and hold a significant load
- **Cantilever Arms**
  - Designed to keep weight low while retaining structural integrity.
  - Seven foot Carrier Fiber rods
  - 3D Printed Nylon Carbon Fiber parts
  - Laser cut Acrylic plates
- **Suspension**
  - A system of five pulleys holds the apparatus upright
  - The rope is secured near the user with a rope cleat for easy adjustment
- **Counterweight**
  - Mounted to the back of the backpack frame, the counterweight, along with the battery produces the backward torque necessary to balance the system

Results

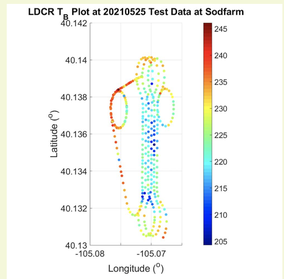
NDVI Raw Data Output



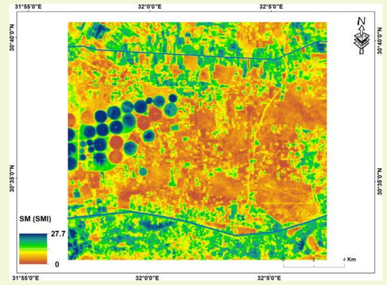
GPS Raw Data Output



Expected Real-time VSM Map



Expected Final VSM Map



Smaller Spatial Resolution	Higher Sensing Accuracy	Real Time Mapping System
Decameter	VSM Estimation Error 3%	Non-Real Time
Portable Structure	**NDVI Sensor**	**GPS & Paspi 400**
Meter	VSM Estimation Error 1-2%	Real Time Mapping