DropBot: A Custom Drone for Precision Water Droplet Penetration Testing

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Soil hydrophobicity plays a crucial role in water infiltration, affecting agriculture, environmental sustainability, and land management. The Water Droplet Penetration Time (WDPT) test is a standard method for assessing soil hydrophobicity, but traditional manual testing is labor-intensive, inconsistent, and impractical for large-scale assessments. To address these limitations, this study presents DropBot, an autonomous drone system designed to conduct precise and repeatable WDPT testing with minimal human intervention.

DropBot features a lightweight, 3D-printed structure with a self-leveling mechanism to ensure stable droplet placement on uneven terrain. The system integrates a servo-controlled droplet release mechanism, replacing traditional pipette-based methods to enhance accuracy and repeatability. Additionally, lux and Time-of-Flight (ToF) sensors, along with an IMX179 USB mini camera, provide real-time data acquisition and monitoring. The drone operates using ROS-based automation, enabling autonomous flight, data collection, and wireless communication with a ground station for live monitoring and post-experiment analysis.

Field tests demonstrated consistent and reliable soil hydrophobicity measurements, validating DropBot's effectiveness in various environmental conditions. The system significantly improves efficiency, accuracy, and scalability over manual methods, making it a valuable tool for agricultural monitoring, land restoration, and climate impact studies. Future enhancements include machine learning integration for adaptive droplet placement, improved battery life for extended field operations, and expanded sensor capabilities to assess additional soil properties.

DropBot represents a significant advancement in automated soil testing technologies, with potential applications in precision agriculture, environmental research, and planetary exploration. By combining robotics, automation, and sensor integration, this innovation provides a scalable and efficient solution for soil hydrophobicity assessment, paving the way for further advancements in drone-assisted environmental monitoring.