Integrating Thermal Imaging and Machine Learning for Soil Moisture Estimation

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Abstract

Water conservation is paramount in addressing global resource challenges, with agriculture representing a major area for potential improvement. Traditional soil moisture measurement methods often prove inadequate for large-scale agricultural operations, leading to an exploration of imaging-based techniques. While RGB and multispectral imaging present certain limitations, thermal imaging offers a promising alternative, particularly when combined with accessible hardware and software. This research focuses on developing a non-contact soil moisture estimation system to optimize irrigation practices and mitigate water waste using thermal images of soil.

This study investigates the feasibility of using thermal images, coupled with machine learning algorithms, to accurately classify soil moisture levels. Different thermal image features were analyzed and machine learning classifiers to identify effective approaches for distinguishing between different soil moisture states. Recognizing the influence of environmental factors on thermal data, the research also examines the relationship between ambient and thermal temperatures to develop a model for estimating soil moisture content. Building upon these estimation capabilities, the study addresses the critical issue of irrigation optimization. By analyzing the temporal dynamics of soil temperature and moisture, we examined the benefits of specific irrigation timings and implemented a model predictive control strategy to regulate water applications. This approach aimed to minimize water waste while ensuring optimal soil moisture conditions for plant growth. This research contributes to the development of practical, non-invasive tools for precision agriculture, with a focus on enhancing water efficiency in agricultural settings.

Keywords: Soil Moisture, Thermal Imaging, Machine Learning, Model Predictive Control

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