

Design of a Modular Automated Plant Watering System for Scalable Agricultural Applications

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BACHELOR'S DEGREE

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I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

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ABSTRACT

DESIGN OF A MODULAR AUTOMATED PLANT WATERING SYSTEM FOR SCALABLE AGRICULTURAL APPLICATIONS

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This research investigates the development of a decentralized, edge-computed automated precision irrigation system to mitigate resource inefficiencies and physiological crop stress in commercial agriculture. Focused specifically on the moisture demands of *Capsicum annuum* (chili pepper), the study engineered a modular mechatronic "unit cell" utilizing ESP32 microcontrollers, capacitive soil moisture sensors, and relay-actuated localized pumps. By employing closed-loop feedback logic, the architecture maintains Volumetric Water Content (VWC) within strict biological thresholds, effectively eliminating reliance on manual scheduling and neutralizing the "cycles of stress" inherent to traditional farming methods. Experimental results demonstrate high system reliability, successfully increasing water application efficiency while drastically reducing both deep soil percolation and surface evaporation. Furthermore, the edge-computing logic exhibited autonomous adaptability by suppressing actuation during heavy precipitation events, protecting the root zone from fatal anoxic conditions. By delivering precise micro-doses strictly within the active root zone, the system also significantly reduced physical fertilizer dependency and minimized nutrient leaching. Economically, the modular mechatronic architecture provides a linearly scalable framework for commercial deployment. By optimizing operational expenditures (OPEX)—specifically through water conservation, reduced fertilizer requirements, and labor optimization—while reclaiming yield losses previously caused by moisture stress, the system generates a robust financial return. The study concludes that low-cost mechatronic automation serves as a viable, sustainable intervention for democratizing precision horticulture and maximizing overall farm profitability. Keywords: Precision Agriculture, ESP32, Capacitive Soil Sensor, Volumetric Water Content, Edge Computing, Break-Even Analysis.

DEDICATION

I dedicate this thesis to my alma mater, Swiss German University, in fulfillment of the academic requirements for the undergraduate program in Mechatronics Engineering.

This work represents the culmination of my academic journey and is the result of my own dedicated efforts. I sincerely hope it provides valuable insights and encourages a deeper understanding among its readers, ultimately contributing to the advancement of smart agriculture and the future of sustainable, technology-driven farming.



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and contribute to a deeper understanding of topics relevant to both academic and industrial development in the future.



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