ElectroCap Project Proposal

Plant Management System

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1. Advisors and Mentor

- Scientific Advisor:
- Scientific Co-advisor:
- Coordinator: Prof. Duarte Mesquita e Sousa
- Mentor:

2. Problem definition

The primary problem we are addressing is the lack of accessible, preventive care for domestic and small-scale plant growers, who often struggle to manually balance complex environmental variables, such as pH, moisture, light, temperature, and nutrients, only reacting when irreversible visual damage to the plant has already occurred. While precision agriculture solutions exist, they are prohibitively expensive and overly complex for single-pot or small-scale applications. To bridge this gap, our proposed system must navigate several strict constraints. Fiscally, the solution must remain highly affordable for the average consumer, limiting our hardware choices to low-cost components rather than laboratory-grade equipment. Technically, we face hardware and computational limitations; the Raspberry Pi lacks native analog inputs, necessitating external ADCs, and possesses limited processing power, which demands highly optimized AI and computer vision models to run locally without overheating. Finally, we must account for environmental constraints, as budget-friendly sensors are highly susceptible to rapid degradation and galvanic corrosion when continuously exposed to moist soil, requiring a careful design balance between cost, accuracy, and system durability.

3. Solution beneficiaries

The primary beneficiaries of our proposed solution are domestic plant owners, urban gardeners, and botanical hobbyists who lack specialized horticultural knowledge but wish to maintain healthy indoor or balcony plants. For these individuals, the device acts as an accessible, intelligent assistant that significantly reduces the cognitive load and guesswork involved in plant care, leading to decreased plant mortality and increased user confidence. Additionally, small-scale cultivators and operators of localized domestic greenhouses represent a crucial secondary group of stakeholders; they stand to gain a cost-effective, data-driven tool that optimizes resource usage, such as targeted watering and precise fertilization, thereby improving plant health and yield without the prohibitive capital investment required by industrial agricultural systems. Ultimately, by democratizing access to precision monitoring, the project empowers everyday users to adopt more sustainable, efficient, and rewarding cultivation practices.

4. Technological solution

Our technological solution is composed by monitoring system that integrates both hardware sensors and computer vision, processed locally via a Raspberry Pi. At its core, the system utilizes a suite of low-cost, soil-level sensors, including capacitive moisture, pH level, and an external photovoltaic cell acting as a pyranometer, interfaced through an Analog-to-Digital Converter (ADC) to collect continuous environmental data. Concurrently, an integrated camera captures visual data of the plant, which is then analyzed by an optimized, lightweight Machine Learning model to detect early signs of stress, such as chlorosis or wilting. By fusing this structured sensor data with unstructured visual analysis, the system generates a high-fidelity 'confidence score' regarding the plant's health. This approach directly addresses our constraints: it provides intelligent, real-time preventive diagnostics while maintaining low hardware costs, and sidesteps the Raspberry Pi's computational limitations by employing efficient edge AI models, ensuring the entire system remains affordable, functional, and durable for domestic use.

5. Competitors and previous work

- Competitors:
- Xiaomi-> Mi Flora
- NEVEANCE Medidor De Solo 4 Em 1

6. Solution requirements

To effectively address our defined problem, the proposed solution must satisfy a comprehensive set of functional, performance, usability, and reliability requirements. Functionally, the system is required to accurately acquire and synchronize multi-modal data by interfacing five distinct analog sensors through an external ADC to a Raspberry Pi, alongside capturing real-time visual inputs via an integrated camera. From a performance standpoint, the embedded Machine Learning and computer vision algorithms must be meticulously optimized to run locally on the edge device, ensuring timely processing without exceeding the Raspberry Pi's computational or thermal limits. Usability requirements dictate that the system must synthesize this complex, interconnected data into an intuitive 'confidence score,' providing non-expert domestic users with clear, actionable insights rather than overwhelming raw metrics. Furthermore, to ensure long-term reliability, the physical architecture must incorporate practical safeguards against environmental degradation—such as mitigating the galvanic corrosion of soil-based sensors—thereby guaranteeing a durable, safe, and user-friendly experience.

7. Technical challenges

Developing this system presents several significant technical challenges across both hardware and software domains. In terms of hardware design, the Raspberry Pi lacks native analog inputs, requiring the integration of a multi-channel Analog-to-Digital Converter (ADC) to interface with the environmental sensors, which introduces complexities in signal conditioning and noise reduction. Furthermore, ensuring the operational longevity of low-cost soil sensors in consistently damp environments demands strategic hardware mitigation against rapid galvanic corrosion. On the software side, a primary obstacle is performance optimization; deploying computer vision algorithms and data fusion models locally on a resource-constrained edge device necessitates highly lightweight architectures to prevent thermal throttling and memory overload. Finally, algorithmically synthesizing continuous tabular sensor data with discrete visual captures into a reliable, synchronized 'confidence score' presents a substantial data management and sensor fusion challenge that must be carefully engineered.

8. Partners

Work in progress

9. Testing and validation metrics

To rigorously assess the performance and reliability of our proposed system, we will employ a comprehensive suite of testing and validation metrics across both hardware and software domains. On the hardware level, sensor accuracy, calibration drift, and ADC signal integrity will be continuously measured to ensure dependable environmental data acquisition, particularly for the degradation-prone soil sensors. For the computational and AI components, standard machine learning evaluation metrics, such as precision, recall, and F1-score, will be utilized to validate the diagnostic accuracy of the computer vision models. The algorithmic confidence score will be empirically validated by cross-referencing the device's automated preventive alerts with the plant's health outcomes, ensuring the final product consistently meets quality standards and satisfies user expectations without generating disruptive false positives.

10. Division of labor (I)

Joel Amorim	João Chorão	Salvador Silva
Scientific research	**Software**	**Website and smartapp**
Botanical Benchmarking	Backend Logic	Website development and updates
AI Dataset Curation	Edge AI Implementation	Smartapp development and updates
Data Fusion Modeling	Network Architecture	Machine learning development
Experimental Design and Validation	Hardware-Software Integration	AI implementation

11. Division of labor (II)

José Garcia	Rodrigo Gomes	
Blogue and HR	**Hardware**	
Blogue updates	Component buy list	
Human resource management	Main circuit project	
Partnerships	Main circuit assembly	
Meeting arrangements	Main circuit testing	

12. Schedule

Semanas 2-4: Planeamento e Aquisição

Definição do problema, utilizadores e requisitos do sistema.

Desenho da arquitetura (diagrama de blocos) e Lista de Material (BOM).

Encomenda de componentes (Raspberry Pi, ADC, sensores, câmara).

Preparação do ambiente de desenvolvimento (SO e bibliotecas).

Semanas 5-8: Desenvolvimento de Hardware

Montagem eletrónica base e ligação do ADC ao Raspberry Pi.

Integração, teste e calibração dos 5 sensores analógicos (solo e ambiente).

Configuração da câmara e validação da aquisição de dados brutos.

Semanas 9-13: IA e Integração do Sistema

Treino/Otimização do modelo de Visão Computacional para o Raspberry Pi.

Desenvolvimento do algoritmo de Sensor Fusion (cálculo do Confidence Score).

Programação da lógica de decisão e do sistema de alertas ao utilizador.

Semanas 14-17: Testes, Validação e Entrega

Implantação do protótipo em ambiente real (teste num vaso com planta).

Avaliação das métricas de validação (precisão da IA e fiabilidade dos sensores).

Redação do relatório técnico final e documentação.