AI-Powered Precision Agriculture: Revolutionizing Water Use from Aquifer to Harvest with Hydroponics and Hydrogel

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Citations

Abstract

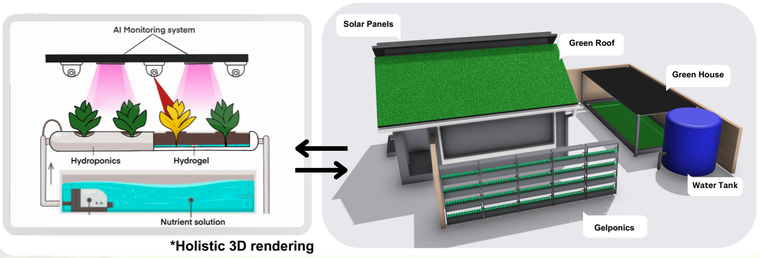
This concept design paves the way into a new era of precision agriculture tailored for modern urban farming, emphasizing the pivotal role of AI-driven technologies. By innovatively integrating rain and wastewater harvesting with cutting-edge hydrogel film and hydroponics, we aim to establish self-sustainability in agriculture[1][7]. At the heart of our design lies advanced AI analytics, pivotal for real-time monitoring and analysis of plant health and environmental conditions. This intelligent system ensures optimal hydration through efficient water collection and usage, fine-tuning nutrient delivery with precision, enhancing plant growth while drastically reducing resource waste. The hydrogel film technology plays a crucial role by maintaining water retention ensuring plants remain hydrated, even under challenging conditions. At the same time, its transparency offers complete visibility into root health[9]. This smart agricultural solution stands as a testament to the potential of AI in transforming farming practices, offering a scalable, resource-efficient method that leverages the best technology to promote sustainability and high yields in urban settings [12].

Mission

Our primary goal is to implement local sustainable agricultural practices in Oxnard by embracing water-saving techniques and employing intelligent resource management strategies, augmented by AI technology. By doing so, we aim to enhance water efficiency within our community and combat food scarcity issues in a cost-effective and scalable manner [4]. We aim to conserve water and reduce pollution from food transportation and soil contamination. By reducing the agricultural footprint and transitioning to a high-tech community, we seek to empower and modernize local farming communities. Looking ahead, our vision extends beyond Oxnard, as we aspire to showcase the power of our approach on a global scale.

System Design

Our innovative system is designed to revolutionize sustainable living and agriculture by integrating several cutting-edge technologies into a holistic ecosystem. The system collects rain and wastewater, storing it in a tank[5]. This water then supplies our agricultural system, consisting of gelponics and hydrogel films, which ensure optimal hydration and nutrient delivery to individual plants[1][7]. Complementing this, a green roof not only enhances the house's insulation, contributing to energy efficiency, but also provides aesthetic beauty, water filtration, and noise reduction[3]. It creates a lush space that supports local flora and fauna, fostering a connection to nature. To further our commitment to sustainability, the system incorporates solar and geothermal energy, drastically reducing reliance on non-renewable energy sources[2][3]. A sophisticated filtration process ensures the water used is clean and safe, closing the loop on our self-sufficient ecosystem. At the heart of our operation is an advanced AI system capable of intricately monitoring plant health, delivering precise nutrient doses tailored to the needs of each plant. It also intelligently controls the greenhouse environment, from temperature to pest management, ensuring optimal growing conditions.



*Holistic 3D rendering

Gelponics

Collecting and Recycling Water

In Oxnard City, with 26.14 inches of rainfall in 2023, our model could capture up to 16,206 gallons from a 1,000-square-foot roof, accounting for losses like evaporation [5]. This stored rainwater, along with filtered household wastewater, supports our hydroponics and hydrogel systems year-round, optimizing water expenditures.

Hydroponics and Gelponics

Hydroponics transforms conventional farming with its soil-less method, which allows for optimized use of space in urbanized environments. Furthermore, hydroponics enables continuous, season-independent cultivation, breaking free from the constraints of seasonal changes [6]. To compliment the strengths of hydroponics, we intend on integrating hydrogels, a novel approach to further enhancing water conservation efforts, and coining a new term, gelponics.


Hydrogel in a tray


Visible roots inside the hydrogel film

If synthetic hydrogels can increase the saturated hydraulic conductivity in sandy soils, a measure of how easily water moves through saturated soil pores, we can conclude and apply the use of bio-hydrogels as a biodegradable alternative that makes use of similar water retention functionality [7]. The application of gel instead of just water allows for an even more precise level of environmental control—temperature, humidity, light intensity, and nutrient levels—ensuring consistent, high-quality yields [8]. Our studies indicate that combining hydrogels with hydroponics into what we'll be calling gelponics can enhance water efficiency by 80-85% over traditional hydroponics [9]. This method helps farmers combat drought effects in the summer and reduces water consumption, leading to improved crop yields and greater sustainability.

Integration of Gelponics, Hydroponics and AI

A key experimental focus of our initiative involves evaluating the performance of a hybrid medium combining hydrogel and peat moss, alongside innovating nutrient-enriched hydrogels for optimal plant sustainability. This aligns with our overarching strategy of harnessing hydroponics and hydrogel technologies to revolutionize agriculture by improving space efficiency and reducing water use. Additionally, we aim to engineer a hydrogel film adaptable to the angled exteriors of buildings, further expanding viable planting areas. The development of a completely gel-based planting medium complements our AI-driven by enhancing visibility due to its transparancy so that we may have valuable insights into plant well-being and growth.

Execution and Impact

This summer we will execute our design. Our focus is on experimenting with a range of hydrogels alongside a rudimentary AI system. As we transition out of summer, we aim to have a functional prototype alongside comprehensive data. This project will evolve with us throughout our academic journey, serving as a foundation for our professional growth. Our goal is to create an eco-friendly hydrogel from local resources, accessible to consumers. Through this initiative, we aim to fortify our community, positioning it as a forefront of sustainable living and a pioneer in advanced agricultural practices. Our mission extends beyond increasing farm output; It's about creating a community focused on lasting environmental care and innovative ideas, securing our leadership in shaping the future.

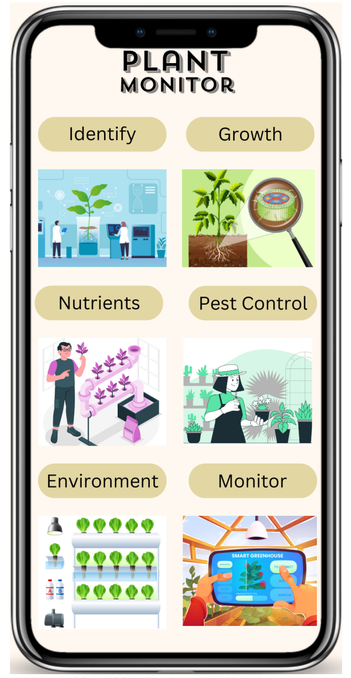
AI-driven Data Monitoring

Designing an Innovative Plant Health Monitoring App

Our innovative application leverages the combined power of TensorFlow, OpenAI, and Nvidia Jetson to bring users a seamless and intuitive experience in monitoring plant health. Using advanced sensors and cameras, our AI system analyzes plant health metrics in real time, ensuring optimal growth conditions. With the integration of hydrogel technology, we effortlessly gather crucial data on plant roots, providing invaluable insights into their well-being.

Making Predictions with TensorFlow

The first step involves loading the pre-trained TensorFlow model into memory. This model has been trained on a dataset to recognize specific features or objects within images [10]. Once the model is loaded, the input image, either selected from local storage or captured using the camera, is processed to prepare it for prediction. This may involve resizing, normalization, or other preprocessing steps to ensure compatibility with the model's input requirements. With the processed image as input, the TensorFlow model performs inference to generate predictions. These predictions could include identifying objects, classifying images, the nature of the trained model [11]. The output of the TensorFlow or detecting patterns, depending on model consists of predicted labels or classes, along with corresponding confidence scores. These results are interpreted to determine the most likely prediction and its associated confidence level.



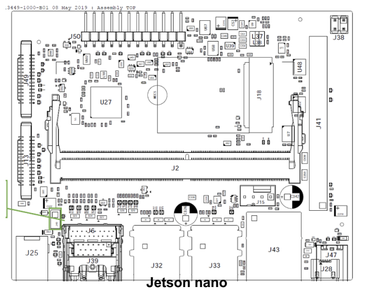
Plant Monitoring Application

Leveraging OpenAI API for Customized AI Development

We have the capability to utilize OpenAI's API key to integrate our own TXT file containing research data encompassing plant health, growth patterns, environmental requirements, nutrient specifications, water levels, and other pertinent information. We possess the capacity to ingest an entire directory of such information [12]. Furthermore, we are exploring the option of incorporating a ChatOpenAI Language Model (LLM) into our system, which would facilitate the integration of external data. However, we are currently evaluating whether this integration is the optimal choice for our system. We also have the flexibility to maintain a fully customized system without integrating the ChatOpenAI LLM, as we continue our research to determine the most effective approach for our needs.

Future Applications of Jetson Nano Technology

We aim to train a Nano Jetson for our research. With our eyes set on revolutionizing hydroponics and hydrogel systems, our goal is clear: to nurture plant growth in the most efficient and sustainable manner possible. By leveraging the capabilities of the NVIDIA Jetson Nano, we are poised to collect valuable data directly from plants within these systems using camera and sensor. To gather firsthand data from the very plants we aim to nurture, gaining insights into their needs and behaviors like never before. Through this fusion of technology and passion for agriculture, we're crafting a narrative of innovation and sustainability—one where every data point brings us closer to a greener, healthier future. Jetson Nano makes the best perfect platform for our research because it has up to 64GB of unfiled memory with 275 tera-ops in a small power efficient form [13]. We intend to leverage the Jetson Nano to train and deploy specific task tailor to our hydroponic and hydrogel system. Jetson Nano supports TensorFlow. Within each detection ROI (Region of Interest) it will also sub-detect color changes on leaves and roots.


Jetson nano