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Encapsulated Gardening Grounds (EGG)

Senior Design

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Background

The Encapsulated Gardening Grounds, otherwise known as the EGG, is a self-contained gardening system paired with an interactive desktop application. Each EGG unit features a soil-based growing environment equipped with sensors for monitoring temperature, humidity, soil moisture, and soil nutrient contents, considering the Nitrogen, Phosphorous, and Potassium contents of the soil. These readings are logged locally and can be reviewed through a web interface hosted by the unit itself. A small pump and irrigation system—triggered automatically or manually via the application's interface—ensures proper hydration of crops. Additionally, the control of fans enables humidity control for the encapsulated grounds. The system is optimized for short-root plants and designed to be space-efficient, making it ideal for indoor or limited-space environments.

The EGG aims to make crop cultivation more accessible and sustainable by automating essential tasks and providing real-time feedback. Users gain insight into the conditions of their crops, receive tailored advice for maintenance, and maintain full control over the system remotely. Whether used in a personal home, urban apartment, or educational setting, the EGG empowers individuals to manage their own agriculture with minimal resources and technical knowledge.

Key Requirements

Outlined below are the prospective client's high-level requirements that the Encapsulated Gardening Grounds must satisfy:

- **Collection of Crop Data:** Utilizing various sensors, various characteristics of the growing crop(s) within the EGG must be measured, including the current Humidity, Temperature, Moisture Level, and information concerning the Soil's Nutrient Contents.
- **Automated Hardware:** The EGG must include hardware enabling the automation of both Irrigation and Humidity control.
- **Control and Data Parsing via a Desktop Application:** The data parsed from the sensors must be able to be viewed with an associated desktop application. Additionally, the hardware features must be able to be controlled with this application.
- **Automation:** The controlled aspects of the EGG must be able to be scheduled and automated through some means, including the usage of the desktop application.
- **Physical Requirements:** The physical assembly of the EGG must allow for the crop(s) growing within it to successfully grow in an indoor environment, taking into consideration the above requirements.

Architectural Design

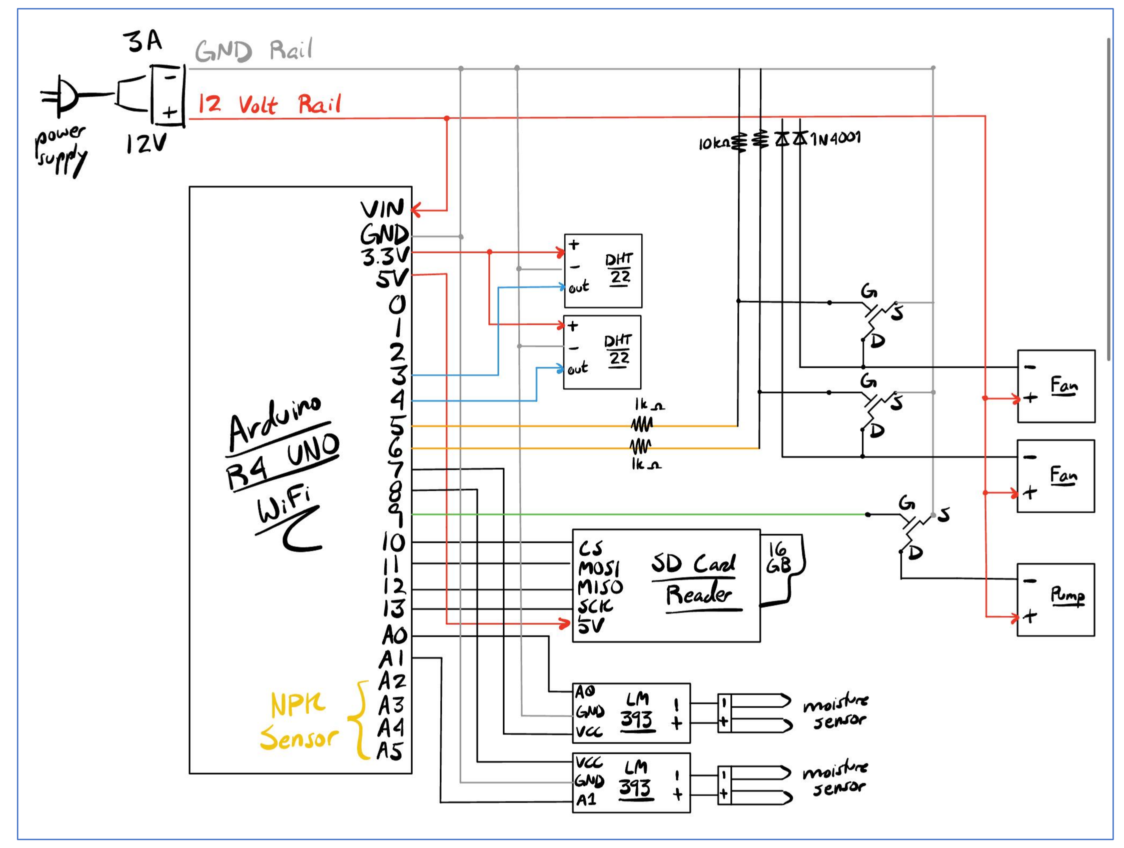
High-Level Design Decisions:

The Encapsulated Gardening Grounds (EGG) system is designed around the integration of an enclosed, self-sustaining agricultural environment with a remotely accessible control and monitoring interface. At its core, the EGG architecture comprises a microcontroller-based control unit (Arduino) responsible for sensor data acquisition, actuator control (with both pumps and fans), and hosting a locally served HTML interface, that is further interfaced by the associated desktop application and automated, scheduled jobs.

The system utilizes soil moisture, temperature, and humidity sensors to monitor environmental conditions. These data points are logged periodically to an SD card in JSON format, enabling both real-time monitoring and historical analysis via the desktop application. Users interact with the system via a Wi-Fi-accessible application interface that allows for both the manual and automated usage of automated systems and access to the logged sensor values. These values are parsed and demonstrated to the user with an intuitive interface to better understand the growth of the EGG's crops throughout its life.

Design Constraints:

The project operates under several design constraints, including a physical footprint suitable for short-root crops, a target water usage of only a few cups per day, and an ongoing, limited budget. These constraints influenced key decisions throughout early design efforts. A conceptual comparison of hydroponic and soil-based systems led to the selection of a soil-based irrigation strategy, favoring simplicity, affordability, and better accessibility for typical users. The modular architecture allows for scalability, and future integration with cloud services remains feasible. Ultimately, EGG's design emphasizes reliability, low maintenance, and user empowerment through data transparency and intuitive control.



Implementation Details

Hardware:

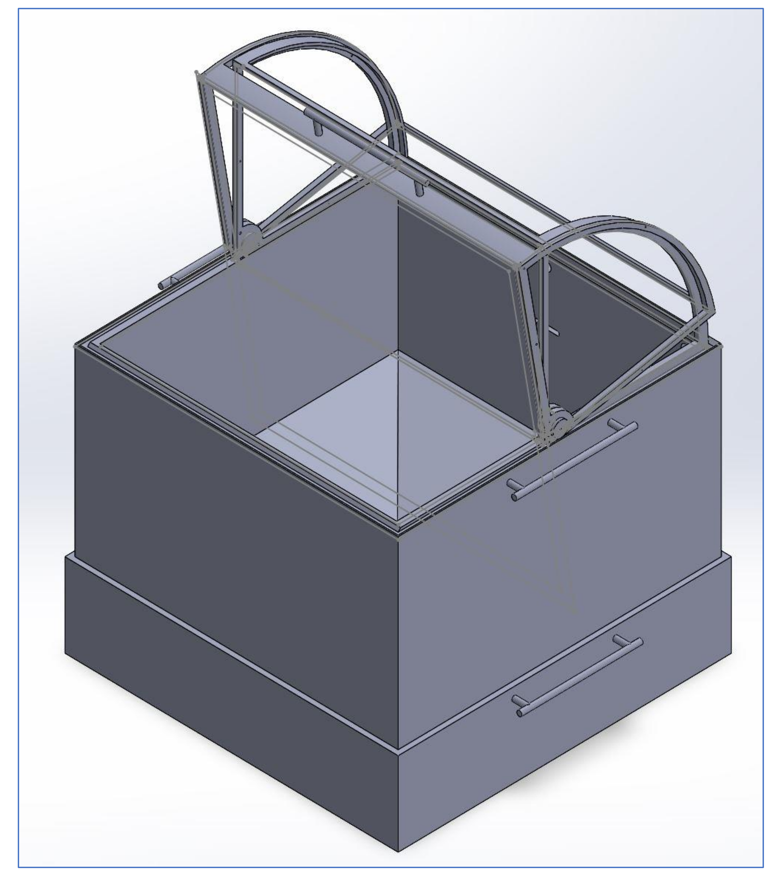
The EGG utilizes an Arduino UNO R4 WiFi as its beating heart. The Arduino was chosen for its IoT capabilities and requisite performance to drive the various sensors and automated options. These are all connected with a comprehensive circuit displayed above. The sensors include two DHT22 Temperature/Humidity sensors, two Moisture Hydrometers, and an NPK Soil Nutrition Sensor. Additionally, the EGG uses two fans for humidity control, and a water pump for automatic irrigation. In addition to parsing the sensors and controlling the peripherals, the Arduino hosts a local HTML site to interact with the desktop application, taking control inputs and sending real-time JSON logs to offer detailed information and advice to the client.

Software:

Many of the EGG's features are realized with the associated desktop application. This React application showcases an intuitive interface to control the various features of the EGG, and the parsing of the EGG's sensor's data in real-time. The Front-End desktop application interacts with a separate Linux machine to run cronjob-scheduled tasks to be performed by the EGG's hardware, allowing the automation of the unit's irrigation and humidity control. Additionally, this setup enables persistence of the EGG's operation, ensuring that scheduled watering and humidity control still occurs.

Physical Assembly:

The EGG is built primarily of pressure-treated wood lined with a waterproof lining for the top and bottom assemblies. The bottom assembly acts both as the EGG's drain pan and water reservoir to water the crops held within the top assembly, which holds both the soil and desired crop. This assembly allows for the growth of crops from a seedling, as opposed to hydroponic solutions. The top assembly is further covered by an encapsulated topper that can be opened as needed to allow for both humidity control and manual operation as needed.



Conclusions and Future Work

The vast majority of the client's features were successfully realized in the creation of the Encapsulated Gardening Grounds. This includes the physical assembly, requisite sensors and hardware, and control of the EGG with an associated desktop application. The following future goals are outlined below, showcasing further improvements that can be made to the client's current solution:

- **Fully remote work:** Allow the EGG to be viewed and controlled away from the EGG's local network.
- **Full NPK Support:** Allow the EGG to properly interpret nutritional values from the top assembly's soil.
- **Grow Lights:** Add additional hardware to use and control grow lights when sunlight exposure to the EGG's crops is suboptimal.

References

The following references show the codified requirements followed during the implementation of the Encapsulated Gardening Grounds:

1. *C. E. A. Alliance, "Commodity specific food safety guidelines for controlled environment agriculture," CEA Standards, 2023.*
2. *WHATWG, "HTML living Standard," https://html.spec.whatwg.org/multipage/, 2025*
3. *IEC12207, "Iso/iec/ieee international standard 12207-2017 - systems and software engineering – software life cycle processes," IEEE Standards Association, 2025.*

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