Modular Agricultural Drone System (MADS)

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Scan for Demos!

Goals & Motivation

Agricultural fertilization remains highly inefficient, with crops absorbing only a limited fraction of applied nutrients, approximately 48% for nitrogen and just 12.6% for phosphorus on a global scale [1,2]. The excess can contaminate groundwater, increase greenhouse-gas emissions, and impose major economic costs; the EPA estimated nitrogen and phosphorus pollution at $2.4 billion in 2015 [3]. An important cause is the widespread use of uniform fertilizer application methods, which ignore spatial variation in plant nutrient demand within a field. As a result, conventional spraying can overfertilize some areas and underfertilize others, reducing efficiency and increasing environmental losses [4]. To address this challenge, we developed a drone-based precision fertilization system that combines aerial sensing, deep-learning-based plant analysis, and targeted spraying. The system first performs a top-level scan of the field to collect image data, which is then processed on a ground station to identify regions and plants that require additional fertilizer. The proposed framework enables localized, perception-guided fertilizer application, offering a path to higher nutrient-use efficiency and lower environmental losses than conventional field-wide methods.

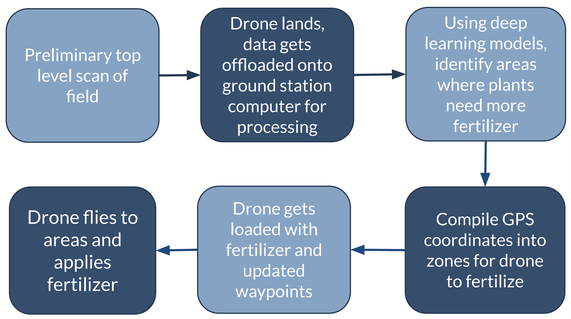
Problem Formulation & Challenges

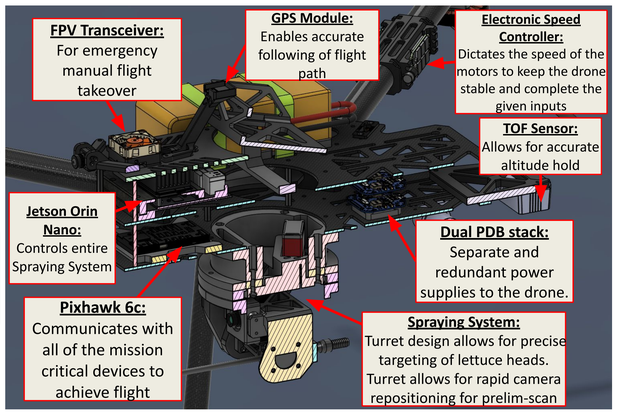
Software: Implementing computer vision algorithms to distinguish nutrient deficient lettuce & Implementing precision sprayer control algorithm. Trying to detect lettuce in a green on green environment and getting reliable ExG metrics

Mechanical: Desining a platform that can carry the desired payload and endurance to meet mission specifications. Drone was made with modularity in mind to support different configurations and mission packages, all the while being cost conscious

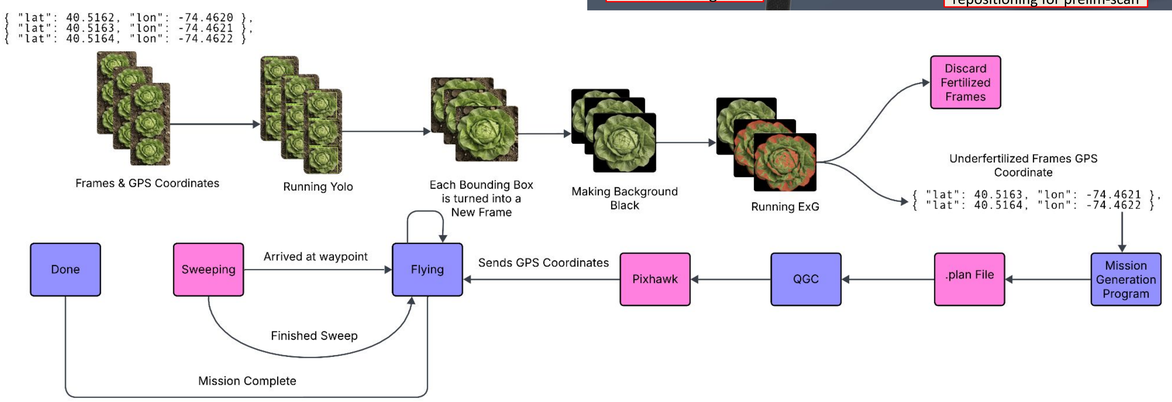
Electrical: Designing both efficient power & electronic hardware architecture that interconnect seamlessly while meeting project requirements and goals. Designing a system that is robust enough to continue flying after having a battery fail

Methodology





1. Hardware Architecture



2. Software Architecture

System Results

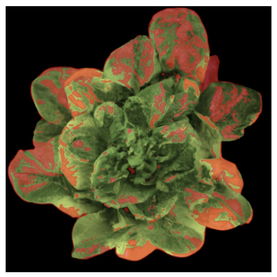
Drone

STATE : ALIGN
PAN : 117
TILT : 184
OBJECTS: 5
SPRAYED: 1

Sprayer Module

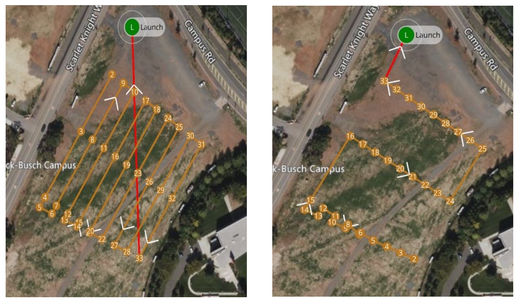
The sprayer module operates through a state machine - sweep, Align, Spray, where it first sweeps the area to locate targets, then use a PID controller to precisely adjust the pan and tilt servo angles, until the spraying system is centered on the object. Once Aligned, the pump is trigged to spray. The Yolo model used with the module maintained a strong minimum confidence score of 81% under harsh real world conditions

Nutrient Stress Detection



The Excess Green Index (ExG) identifies under-fertilized regions by masking yellowed leaf tissue in red, enabling per-plant classification of fertilization status

Path Planning



Nearest neighbor algorithm reorders waypoints to produce a more efficient traversal path by minimizing total travel distance

Plant Detection

YOLOv11 model identifies individual lettuce heads with bounding boxes and confidence scores to enable precise crop spraying

Future Work

1. Improve detection and spraying accuracy to ensure precise fertilizer delivery to identified nutrient-deficient plants
2. Expand on the modular drone capabilities by integrating additional sensors and systems
3. Improving the power system and overall design to achieve improved flight times for larger fields and payloads

References

[1] L. You et al., “Global mean nitrogen recovery efficiency in croplands can be enhanced by optimal nutrient, crop and soil management practices,” Nature Communications, 2023.
[2] X. Luo et al., “The global fate of inorganic phosphorus fertilizers added to terrestrial ecosystems,” One Earth, 2024.
[3] U.S. Environmental Protection Agency, “Nutrient Indicators Dataset,” EPA, 2025.
[4] A. Guerrero and A. M. Mouazen, “Evaluation of variable rate nitrogen fertilization scenarios in cereal crops from economic, environmental and technical perspective,” Soil and Tillage Research, 2021.