ECE 445 Project Proposal

Agricultural Drone Refilling System

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1 Introduction

1.1 Problem

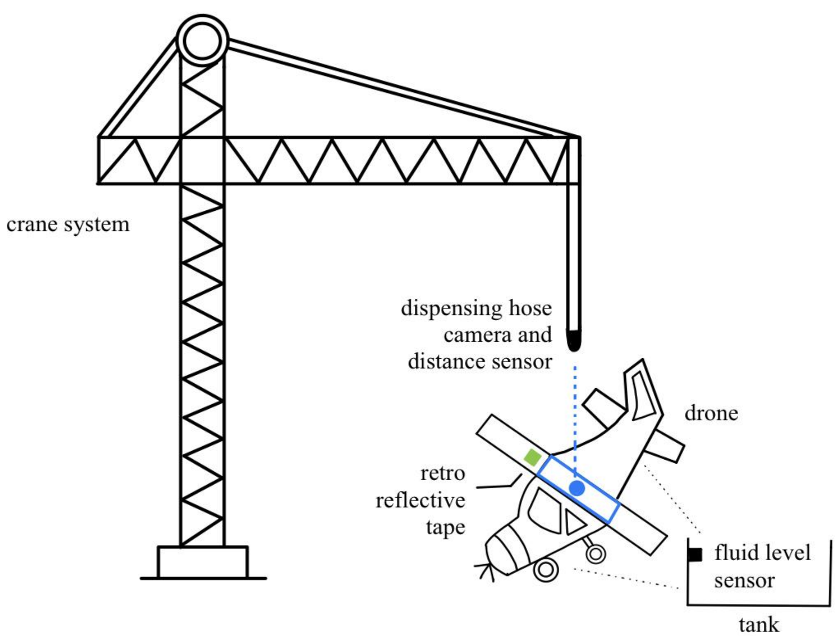
In the past few years, there has been an increased use of agricultural drones to efficiently spray crops rather than human flown aircrafts. In many agricultural drones, the sprayer tank needs to be manually refilled instead of using an automated system. While this does not pose a problem with a small number of drones, as the fleet size increases, tank refilling will take up more time, questioning the efficiency of this current system. This will result in a decrease in productivity as more time will be spent refilling the tanks instead of operating the drones or taking care of other tasks, such as analyzing the data collected from the drones and performing maintenance on various equipment among other examples.

1.2 Solution

An automated refilling system would relieve this issue by refilling the empty sprayer tanks without human intervention. This would free up the farmer and enable the drone fleet to operate more efficiently by reducing the downtime caused by waiting for an empty tank to be refilled. The refilling system would consist of a crane that contains the refilling nozzle, camera, distance sensor, and pumping hardware needed to align the nozzle to the fill port on the drone's tank and refill it. Additionally, a computer and microprocessor would be needed to handle the image processing from the camera and control the crane motors, respectively. Visual markers can be used to determine the location of the fill port, as well as the distance to the fill port, using image processing. The distance sensor would act as a backup to ensure that the crane does not accidentally crash into the drone if the image processing fails to correctly determine the distance to the drone.

1.3 Visual Aid

The image below represents the mechanical design of this project including the main technical aspects.



1.4 High-Level Requirements

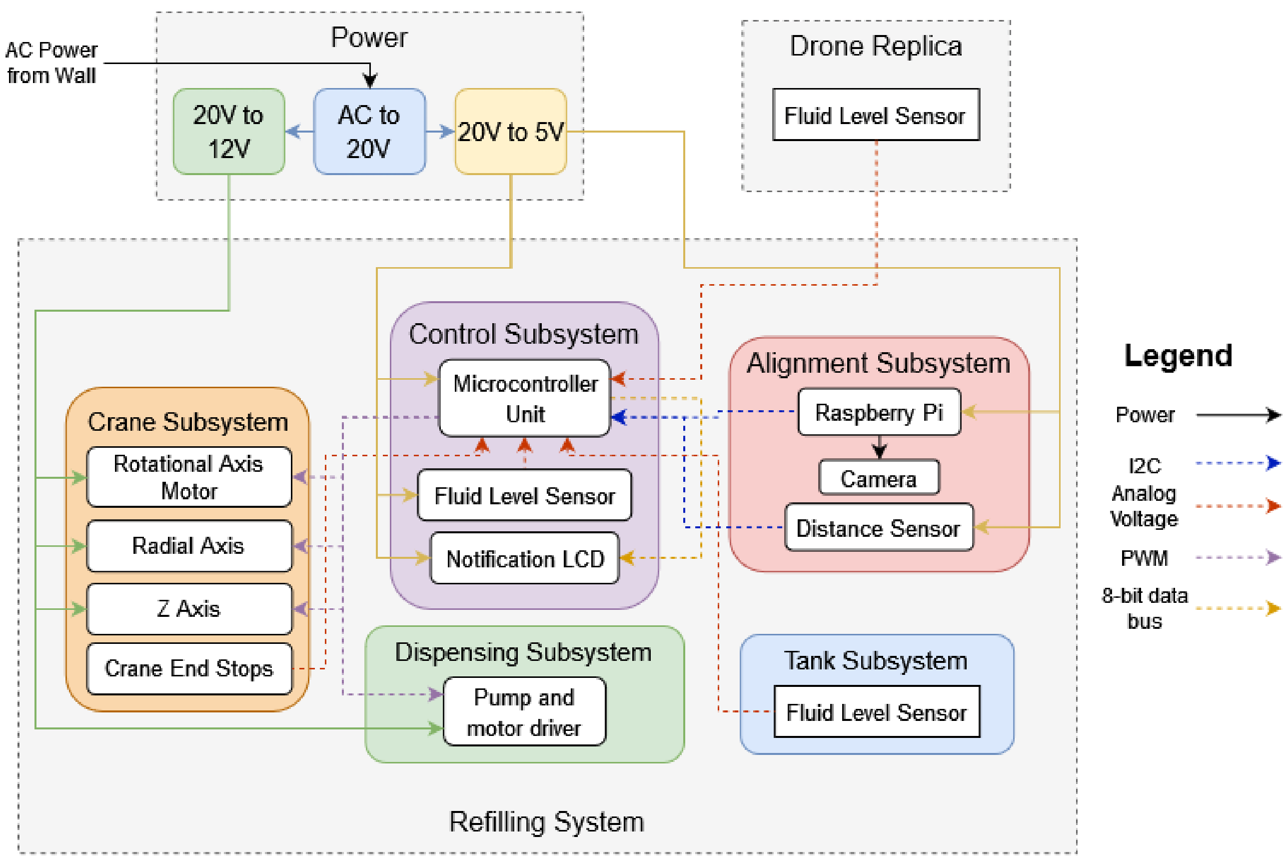
The high-level requirements involved in deeming this refilling system successful are centered around the three main objectives: alignment, dispensing, and reliability.

- Alignment: Being able to locate the fill port using computer vision and image processing is a major component of our refilling system.
- Dispensing: After aligning to the correct location on the fill port, our refilling system must be able to dispense fluid without overflowing or excessively spilling.
- Reliability: The system needs to repeatedly and reliably align and dispense the correct amount of fluid into the drone.

2 Design

2.1 Block Diagram

Below is the block diagram that represents all subsystem aspects of our project.



The block diagram shows all of the power connections in addition to the different data connections as shown in various colors in the Legend.

2.2 Subsystem Overview

There are multiple subsystems that we have as a part of our project, a refilling system, a drone replica and a power system. Within the refilling system specifically, there are five subsystems. These subsystems are a tank subsystem, dispensing subsystem, crane subsystem and alignment system.

Refilling System
The refilling system will automatically align the refilling hose and nozzle with the drone's tank fill port, refill the drone with the product to be sprayed, such as fertilizers or pesticides, and stop filling the drone once the tank is full. Once the refilling process is complete, the station will send a signal to the drone and disengage from the drone leaving it free to move away from the station and take off. The station will accomplish these tasks with the following subsystems:

> **Tank Subsystem**
> This subsystem will have a fluid monitor which will signal to the control system if the refilling station needs refilling.
>
> **Dispensing Subsystem**
> This subsystem will have a nozzle, valve, and hose which handles reliably delivering the fluid to the drone without excess spillage.
>
> **Crane Subsystem**
> This crane-style subsystem will use stepper motors to move the dispensing system in a controlled and precise manner. Given the fact that the subsystem will use stepper motors, there will also be stepper motor drivers to power the stepper motors.
>
> **Alignment Subsystem**
> This subsystem will use a Raspberry Pi for image processing and a camera for accurately aligning the dispensing subsystem with the drone's fill port. Additionally, there is a distance sensor which will prevent the nozzle from crashing into the drone.
>
> **Control Subsystem**
> This subsystem will control crane movement and monitor the refilling process to prevent the drone from overfilling. It will also monitor the tank subsystem's fluid level and illuminate a notification light if the tank needs refilling. If time permits, we will have an LCD display that provides notifications and system statistics.

Drone Replica
The Drone Replica represents a replica of the important parts of the drone including the wing/fuselage area around the fill port, the fill port, visual markers, and a tank with a fluid level sensor. The wing/fuselage mockup will be used to model the actual geometry of the drone in order to provide a realistic testing scenario. The fill port will be on the top surface of the replica such that it will be easily reached by the refilling system. The visual markers will be made of retroreflective material for easy identification by the alignment system. The fluid level sensor within the tank will measure the fluid level inside the tank and alert the station when the desired fill level is reached. The refill status display will display a notification as a representation of the drone receiving a signal that the refilling process has successfully been completed.

Power System
The power system will include an AC/DC power supply and off-shelf voltage regulators to provide the necessary voltages for the different subsystems to run correctly. This aspect of the project is important to make sure the proper amount of power and data is given to all of the different subsystems.

2.3 Subsystem Requirements

The requirements for success within each subsystem are down below:

Tank Subsystem
- Holds the given fluid without leakage
- Signals that the refilling station needs refilling

Dispensing Subsystem
- Refills the tank without overfilling or having an excessive amount of fluid drops

Crane Subsystem
- Moves the dispensing system to the correct location on the drone
- Supports the weight of the dispensing subsystem and fluid during the refilling process

Alignment Subsystem
- Depicts the location of the fill port
- Mates the nozzle with the fill port without crashing into the drone

Control Subsystem
- Fills drone to desired level (using proper detection) without overflow
- Illuminates a notification light if the tank needs refilling
- Operates the crane in a controlled manner without overshooting end stops
- Does not crash the nozzle into the drone replica

Drone Replica
- Represents a mock-up of the important parts of the drone
- Communicates signals back to the station

Power System
- Power supply provides the necessary 5V and 12V with a ±10% margin of error regardless of load on the power supply

2.4 Tolerance Analysis

One aspect of our design that poses a risk to successful completion of the project is the fluid aspect. There is a significant amount of risk when it comes to adding fluids to an electrical system and electrocution is a potential hazard to take into consideration. If we are able to work on a feasible way to bring in the fluid aspect of our project, our project will be successful. One of the particular components that we could use is a hose or tube to refill and fill water into the tank in our drone. We will also keep in mind to cover any parts of our mechanical and electrical system that could potentially be exposed to fluids with plastic or waterproof material. Another aspect of our project that correlates with the fluid aspect of our system, particularly the vacuum pump/hose, which might pose a risk to the completion of our project is making sure that it doesn't coil up in the refilling process for the tank.

The expected peak power draw of our entire system is estimated to be around 100 Watts. Our Raspberry Pi uses 18 Watts, the water pump motor would use about 5 Watts, and, we estimate our stepper motors to use about 24 Watts of power each, making it a total of 72 Watts for the 3 stepper motors used to represent the 3 different axes. We anticipate the extra 5 Watts will be consumed by the various sensors used. Taking this into consideration, we will use a 180 Watt AC to DC power adapter to power our system.

3 Ethics and Safety

3.1 Ethics

Our project complies with IEEE Code of Ethics I-4, I-6, and II-7 [2] as anyone in the agricultural farming industry will be able to have access to this technology. We will be completing this project in a lawful manner while advancing the technological capabilities of agricultural drones.

3.2 Safety

Some of the main safety considerations with this project are injuries caused by a propeller, chemical health hazards associated with agricultural chemicals, especially pesticides, and possible electrocution hazard. The first safety issue is addressed by the use of a drone replica. For both a fixed-wing aircraft and multirotor aircraft, the replica will not have any of the hardware needed to fly, or even spin the propellers even though a propeller might be included. This design decision was made to prevent the possibility of an injury caused during propeller operation. Additionally, the chemical health hazard is addressed with the use of water instead of chemicals. On the other hand, the electrocution hazard will be minimized by keeping all electronics as far away from the fluids as possible in addition to mounting the electronics above the bottom of the station so that any excess spilled fluids do not touch electronics or unintentionally malfunction them.

4 References

[1] B. Coxwroth, "Autonomous Electric Crop Duster gets approval for US demos," *New Atlas*, 13-Oct-2020. [Online]. Available: https://newatlas.com/drones/pyka-pelican-autonomous-electric-crop-spraying-drone/. [Accessed: 01-Feb-2023].

[2] *IEEE Code of Ethics*. (n.d.). Retrieved from IEEE: https://www.ieee.org/content/dam/ieee-org/ieee/web/org/about/corporate/ieee-code-of-ethics.pdf. [Accessed: 07-Feb-2023].