ECE 445 Design Document

Agricultural Drone Refilling System

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1 Introduction

1.1 Problem and Solution

Problem

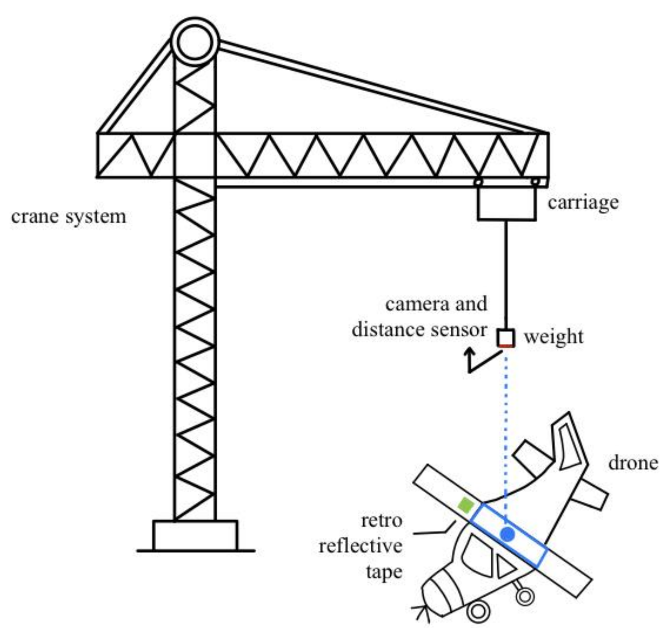
In the past few years, there has been an increased use of agricultural drones to efficiently spray crops rather than human flown aircrafts. In many agricultural drones, the sprayer tank needs to be manually refilled instead of using an automated system. While this does not pose a problem with a small 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.

Solution

An automated refilling system would relieve the issue detailed above 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 mock refilling system would consist of a crane that contains motors, a string with a replica nozzle attached at the end (representing the nozzle and hose), camera, and distance sensor needed to align the replica nozzle to the refilling port on the drone. 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.

1.2 Visual Aid

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



1.3 High-Level Requirements List

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

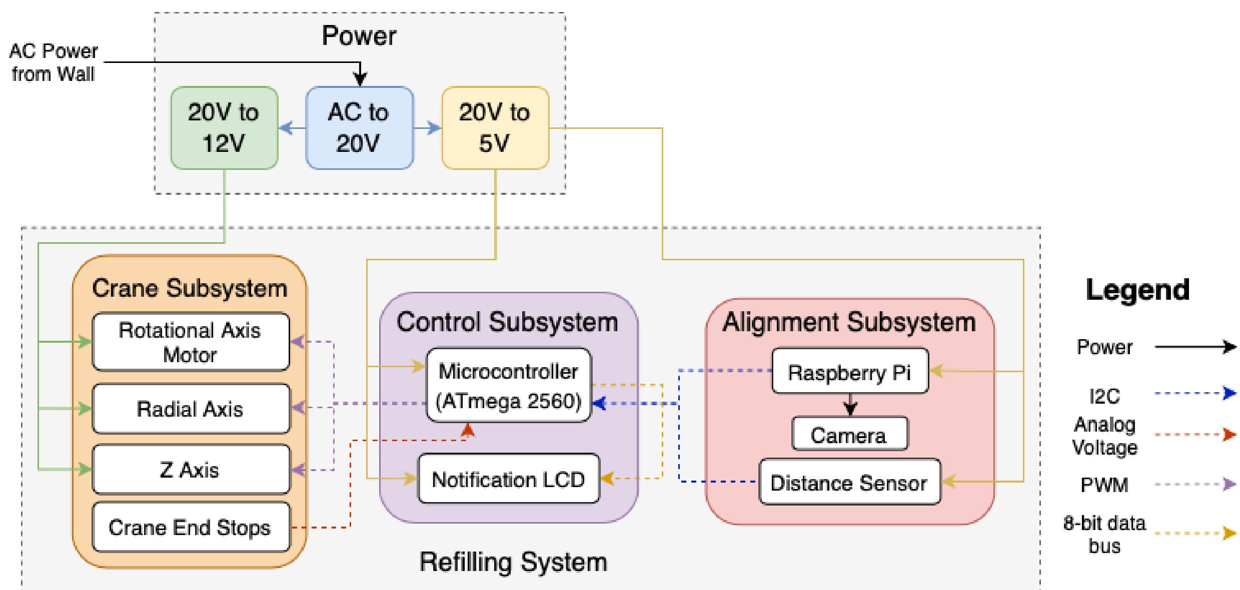
- Alignment: Being able to locate the fill port using computer vision and image processing is a major component of our refilling system.
- Dispensing*: After aligning to the correct location on the fill port, our dispensing system must be able to accurately place the replica nozzle inside the refilling port.
- Reliability: The replica nozzle needs to repeatedly, and reliably, align and place inside the refill port.

*Due to advice from both the machine shop and professor, we have decided to downsize our project by eliminating the fluid aspect of our design. This reduces the complexity of our design and also drastically reduces the construction time of our project by eliminating the need to check for leakage, potential electrocution risk, as well as the complexity associated with pumping the water, preventing spills, and checking the fluid levels in the drone and station.

2 Design

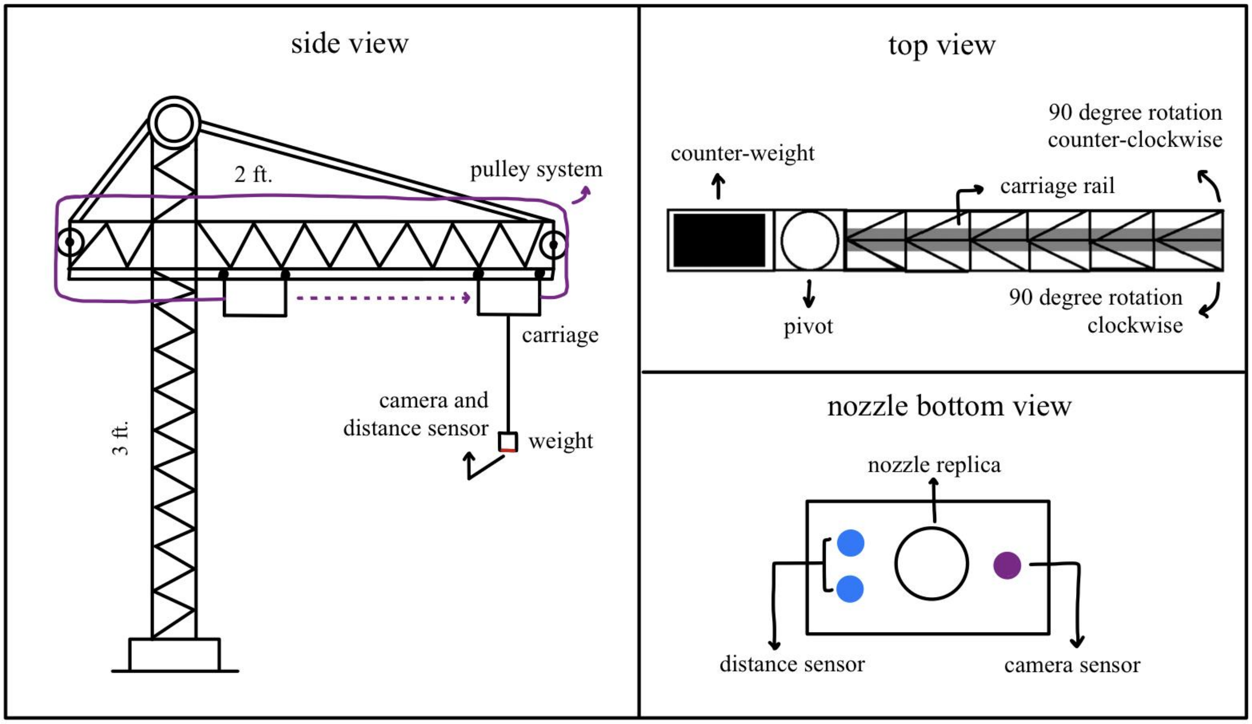
2.1 Block Diagram

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



The block diagram above shows all of the detailed components that will be used for our project including the different power connections as specified in the legend.

2.2 Physical Design



This physical design represents the main aspects of our system, including a side, top and bottom view to detail the crane system, carriage and placement of sensors.

2.3 Refilling System: 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.

Requirements	Verification
Move the dispensing system to the correct location reliably	The crane's movement axes should move in a smooth fashion without getting caught or snagged
Support the weight of the dispensing subsystem	The crane does not break or collapse and remains structurally sound

2.4 Refilling System: 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 replica nozzle from crashing into the drone.

Requirements	Verification
Locate fill port of a drone located in the working area	The system notification should switch from displaying searching notification to the aligning notification
Align replica nozzle to the refill port on the drone	Before the replica nozzle is lowered, the replica nozzle should be above the refilling port
Do not crash the replica nozzle into the drone	The replica nozzle is properly lowered into the refilling port and not dropped anywhere else

2.5 Refilling System: Control Subsystem

This subsystem will control crane movement and monitor the dispensing process to prevent the drone from overfilling. If time permits, we will have an LCD display that provides notifications. The notification panel will display system notifications such as "searching for the refill port", "aligning to the refill port", and "successfully connected to the refill port."

Requirements	Verification
Displays system notifications based on current action	The appropriate system notification is displayed for the current operating mode
Operates the crane in a controlled manner without overshooting end stops	1. The carriage on the crane arm does not fall off the front or back ends 2. The crane does not rotate beyond the designated 180 degree range of operation and potentially cause damage to itself
Communicates with alignment subsystem to align replica nozzle to the refilling port	The crane's axes move appropriately based on the output from the alignment subsystem. For example, if the alignment subsystem tells the crane to rotate counter clockwise by a given amount, the crane will accurately rotate counter clockwise by the given amount

2.6 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, and visual markers. 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 in order to properly locate and align the replica nozzle with the fill port. The only requirement for this subsystem is to represent an accurate mock-up of the important parts of the drone near the fill port.

2.7 Power System

The AC to DC power supply will be the ToolkitRC ADP180 180W power supply. This power supply was chosen because it was already on hand and a new power supply would not need to be purchased. The ADP180 outputs 19.5V which will be converted to the 5V and 12V supply voltages with high amperage voltage regulators.

Requirements	Verification
Power supply provides the necessary 5V and 12V with a ±15% margin of error	A digital multimeter will be used to measure the 5V and 12V lines to ensure that the appropriate voltages are being supplied

2.8 Tolerance Analysis

The expected peak power draw of our entire system is estimated to be around 100 Watts. Our Raspberry Pi uses 18 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 10 Watts will be consumed by the various sensors, display, and the microprocessor. Taking all of these components in our system into consideration, we will use a 180 Watt AC to DC power adapter to power our system to provide an ample power budget.

3 Cost and Schedule

3.1 Cost Analysis

The average salary of a UIUC graduate is $80,296 for an electrical engineer and $105,352 for a computer engineer, which works out to about $38.60 - $50.65 per hour, assuming that there are 2080 work hours per year.[2] Using the average hourly rate of $44.62 per hour, and each team member working about 10 hours per week. For the 10 weeks for the project, the expected labor cost is 44.62*3*10*10 = $13,386. The expected parts cost is conservatively estimated to be around $250, so the total cost of the project, including labor and materials, is $13,636.

Below is a speculative breakdown of the parts that will be used:

Component	Part number	Price per unit	Number of units	Cost
ToolkitRC ADP180 180W AC to DC power supply	ADP180	$0.00 (already owned, $39.99 new)	1	$0.00
Garmin Lidar Lite V3	010-01722-00	$0.00 (already owned, $129.99 new)	1	$0.00

ATmega 2560	ATMEGA2560-16 AUR	$0.00 (free sample available, $18.86 regular price)	3	$0.00
Stepper Motor	17HS16-2004S	$12.99	3	$38.97
20x20 V-Slot Carriage	BT625-BK	$11.99	1	$11.99
20x20 V-Slot Extrusion	US-LR-2020-S	$5.40	1	$5.40
Total Cost of Materials				$56.36

3.2 Schedule

Week	Objectives	Notes
02/20	Create the physical design of the model	Design Document & Team Contract due
02/27	- Have PCB ready for review and ordering - Finalize the CAD model of our project - Speak with the Machine Shop	- Design Review and PCB Board Reviews - Talk with Machine Shop by Tuesday for feasibility of design construction
03/06	- Submit final version of PCB for fabrication - Start building physical components - Order PCB components	- First round PCBway orders must pass audit by 03/07 - Teamwork Evaluation due 03/08
03/13 (spring break)	Start developing the computer vision and mechatronics software	N/A
03/20	- Build and Test PCB (if delivered) - Work on debugging PCB - Continue working on/testing our software	First round PCBway orders, if necessary, must pass audit by 03/28
03/27	- Full System Test! - Debug and make any changes	- Second round PCBway orders - Individual progress reports
04/03	- Finalize any bug fixes and submit updated design for the second round - Test all parts of design again - Continue debugging full system and	Each group mate will take on testing separate parts of the system and debugging, as necessary

	finalizing integration	
04/10	Make sure everything is complete and all of the components are connected	Team Contract Fulfillment
04/17	- Mock demo - Final debugging	Mock demo
04/24	Final demo week	Final demo
05/01	- Finalize and submit final report - Finalize lab notebooks	Final presentation

4 Discussion of Ethics and Safety

Our project complies with IEEE Code of Ethics I-4, I-6, and II-7 [3] 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.

Some of the main safety considerations with this project are injuries caused by a propeller and a pinching/entanglement hazard from the mechanical aspect. 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 pinching and entanglement hazard can be avoided by tying back long hair and clothing as well as keeping hands and fingers away from moving parts when the system is powered on.

5 Citations

[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] https://ece.illinois.edu/admissions/why-ece/salary-averages

[3] *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].