UAV Drone Replenishment: Project Specification

ADCS Dynamics

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Project Charter

Overview

The UAV Drone Replenishment project aims to develop an autonomous drone system capable of performing complex tasks including takeoff, landing, and object manipulation in challenging environments. This project is a drone system sub-division overseen by Triton AI, a University of California, San Diego organization competing in RobotNation's RobotX Maritime Challenge 2024 [1]. The drone will be equipped with cameras, an IMU, GPS, and a flight controller, integrating sensor fusion technologies and autonomous flight software. Successful execution of the drone system refers to the following task designated by the RobotX competition; the UAV (unmanned aerial vehicle - drone) launches from the USV (unmanned surface vehicle - boat), locates a floating helipad, collects a small tin to relocate to another floating helipad, and returns to the USV [1]. Our software will be initially tested via simulation, and then taken through real-world trials to test its ability and functionality.

Execution Strategy and Technical Approach

The difficulty in autonomous drone operations lies in the ability of the drone to estimate its state from sensor data. Our approach is to use computer vision, sensor fusion, and state estimation algorithms to inform the drone's control software. This will be done in phases. The first two phases will be performed in a simulation environment. Initially, the simulated drone will have full knowledge of the state of the UAV and the state of the target landing pad. We will develop the control software necessary to take off and land in this simulation environment. The next simulation environment will require the drone use simulated sensors to estimate the relative state of the drone from the target. These sensors will be analogous to the sensors that will be installed on the drone we will use in the next phase. These sensors are a forward facing camera, downwards facing camera, vertical distance sensor, IMU, barometer, and GPS. After successfully performing the the tasks in the simulator, we will then integrate our software onto the drone. Once integrated, the drone will then be tested at UCSD's aerodrome to perform the required tasks. The specifics of what algorithms we will be using for our technical approach are still under consideration but will be finalized by our second simulation phase.

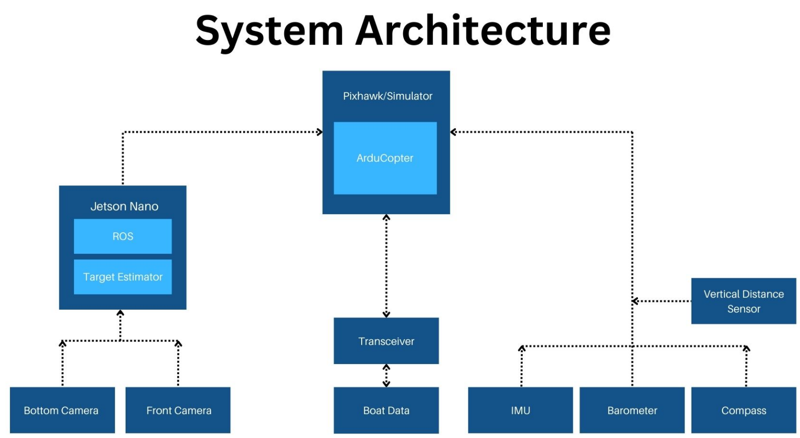

Figure 1: High-level System Architecture Diagram

Minimum Viable Product

The Minimum Viable Product (MVP) for this project will consist of control algorithm software that successfully operates in the SITL Simulator, with the simulated drone capable of stable takeoff, hovering, and landing. We will utilize a cross-language integration approach, developing our machine learning models and neural networks for object detection and decision making in Python, while implementing control logic and system operations in C++.

Beyond the MVP

Once we have written and thoroughly tested our control code using the simulator, we will turn our focus towards real-world implementation. At this stage, we will deploy our software on a sponsor-provided drone to validate its core functionality, testing its capability of succeeding in the UAV replenishment task.

Long Term Goals

The goal for this project beyond this quarter is to fully develop a refined autonomous drone system capable of handling adverse weather conditions and potential obstacles (i.e. moving USV landing platform, wind affecting drone movement, bright reflective light affecting camera's ability to accurately detect colors of tin cans, birds flying in close proximity to drone, etc.). This project will provide the foundation for Triton AI to successfully complete the UAV Replenishment task as outlined by RobotX, supporting the organization in its competition performance.

Risk Management

There are multiple risks in completing our MVP that we have plans to mitigate.

1. The drone may break during testing.
    (a) We will first use simulations to test our algorithms before implementing them on a real drone.
    (b) We will use a cheaper, smaller drone with similar functioning hardware to test the real-world functionality of our algorithms.
2. We cannot acquire the UCSD Aerodrome for testing.
    (a) We have been approved to fly at the AeroDrome and will schedule a test flight well in advance of when we need it.
    (b) We have found alternate locations to test our drone that do not require pre-approval.
3. Our hardware components may have integration issues or failures.
    (a) We have sponsors that provide us with the necessary reliable physical components, and supporting leads at Triton AI who will guide our hardware integration.
    (b) In the event of hardware failures, we may order replacement parts (through the help of our sponsors). As we wait for the new parts to arrive, we will continue to further develop our software and employ simulated tests to ensure we make continued progress and efficiently utilize our time.

Group Management

Team Roles

- **Spokesperson:** Daniel serves as the team's spokesperson, typically initiating communication with the Triton AI team for inquiries and updates.
- **Hardware lead:** Alec holds the final decision-making authority regarding hardware components, leveraging his expertise in embedded systems. Daniel acts as a supporting decision-maker, providing additional input particularly with software/hardware integration.

- **Software lead:** Soumi and Carson are responsible for making final decisions regarding the neural network and the object detection code, drawing on their experience in developing computer vision algorithms.

Decision-making Process

We prioritize informed decision-making in our project, typically by seeking input from our technical sponsors as a starting point. Subsequently, we meet to discuss and reach a consensus, ensuring thorough consideration of all aspects before finalizing any decision. This collaborative approach allows us to make well-informed decisions that best serve our project's goals.

Communication Structure

Our team primarily communicates through Discord for quick discussions and in-person meetings for more in-depth conversations. When consulting with the TritonAI team, we utilize email, cc'ing all relevant parties to ensure everyone stays informed and up to date. We will also participate in mandatory weekly stand-ups to ensure that we are all on the same page and update technical documentation.

Schedule Management Process

We've developed a Gantt Chart with inputs from TritonAI to outline our project's timeline, featuring realistic weekly goals that we strive to achieve. In case of any schedule delays, our strategy is to prioritize tasks according to their importance to ensure delivery of at least the MVP. If necessary, we're prepared to allocate additional time outside our regular schedule to address any outstanding tasks.

Project Development

Team Technical Expertise

The technical expertise of each of the team members has been listed below:

- **Soumi Chakraborty:** Computer vision, machine learning and image processing
- **Alec Digirolamo:** Machine learning and embedded systems
- **Carson Rae:** Robotics, embedded systems, drone systems, machine learning and deep learning
- **Daniel Sanei:** Embedded systems, robotics, software/hardware integration

Testing Infrastructure

For our project, we split testing into three components:

- **Simulation (MVP):** We'll conduct MVP testing in the SITL Simulator, assessing the control algorithm software with a simulated drone capable of stable takeoff, hovering, and landing.
- **Aerodrome (beyond MVP):** We'll integrate the algorithm with the sponsor-provided drone and assess its ability to pick up and deliver tin cans within the UCSD aerodrome testing environment.
- **Real-World Testing (beyond MVP):** We'll test our software in the real world by bringing the full-size boat and drone to a lake. Doing well in this test will be the final step to achieving competition-ready software for the RobotX competition.

Technological Requirements

- **Hardware:** Jetson Nano, Pixhawk Kit
- **Software:** SITL Simulator, OpenCV, PyTorch, ROS, AdruCopter

Documentation Process

We plan to document our progress by maintaining project records during our once-a-week group stand-ups. This will allow us to update one another and keep up-to-date records of the technical aspects of the project. It will also make our collaboration with each other and with consultants more efficient. For documentation, we'll use LaTeX to manage a continuous document and Canva for creating diagrams. This approach will make it easier to share information among our team and with other parties, and it will simplify the process of preparing our Final Report. For the software that will become our deliverable, we will use GitHub to manage the version control and to keep a central repository.

Project Milestones and Schedule

Milestone Priorities

In our project, each phase follows a structured approach consisting of development, maintenance, and testing stages. Our primary emphasis lies on the development tasks, followed by thorough maintenance to ensure smooth integration with the preceding phase. Following this, we subject the entire unit to intense testing, ensuring its functionality and compatibility across all phases.

Table 1: Milestone Priorities

Priority Level	Code
High	H
Medium	M
Low	L

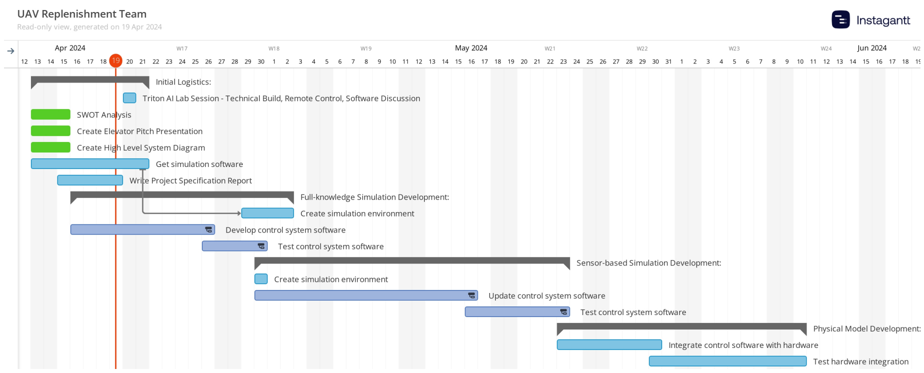

Figure 2: Gantt Chart (April - June 2024)

Defining Milestones

This project will be conducted in a phased approach:

Milestone 1: **Onboarding** This milestone consists of creating initial diagrams, acquiring hardware, and acquiring the necessary software.

Milestone deliverables:

- [H] SWOT analysis (Apr 15)
- [H] High-level system architecture diagram (Apr 15)
- [L] Elevator pitch presentation (Apr 16)
- [M] Project specification report (Apr 19)
- [H] Build drone in TritonAI Lab Session (Apr 20)

Milestone 2: **Full-knowledge Simulation Development** This milestone consists of demonstrating the developed full-knowledge simulation software.

Milestone tasks:

- [H] Develop control system software (Apr 26)
- [H] Test control system software (Apr 30)

- [M] Create simulation environment (May 2)

Milestone deliverables:

- Video demonstration of the working drone on the simulator

Milestone 3: **Sensor-based Simulation Development** This milestone consists of demonstrating the developed sensor-knowledge simulation software.

Milestone tasks:

- [M] Re-create simulation environment (May 2)
- [H] Update control system software (May 16)
- [H] Test control system software (May 23)

Milestone deliverables:

- Video demonstration of the working drone with sensor fusion on the simulator

Milestone 4: **Physical Model Development** This milestone consists of demonstrating the integrated sensor-knowledge software onto the hardware.

Milestone tasks:

- [H] Integrate control software with hardware (May 30)
- [H] Test hardware integration (Jun 10)

Milestone deliverables:

- Video/in-person demonstration of the physical drone taking off, landing, and delivering the tin can in the process

Connections Between Milestones and Team Members

Our team members contribute to logistical and administrative tasks including documentation and report generation, particularly associated with Milestone 1. This collaborative approach ensures that all team members are on the same page, collectively moving forward with project development, idea discussion, and decision-making.

In Milestone 2 and on, our team will delegate tasks based on the skillsets of our individual members. We will create two sub-teams, one consisting of development for the autonomous drone flight software, and a second for the artificial intelligence and machine learning aspects of the replenishment task. Based on relevant experience, we plan to have Alec and Daniel handle the flight software, as Soumi and Carson spearhead the computer vision tasks.

Proof of Milestone Achievement

To validate the completion of each milestone, we will utilize a combination of demonstrations, and testing results. Each milestone will be well-documented with specific tasks and deadlines as progress is made, to ensure a thorough and complete report of all achievements. The MVP implementation of our software will be validated through a video demonstration of the operating drone in the SITL Simulator, alongside relevant and documented testing. For beyond the MVP, we would conduct and document real-world testing of our drone software, with a video recording as our deliverable to demonstrate proof of achievement.

References

[1] RoboNation, "2022 RobotX Team Handbook," 2024. [Online]. Available: https://robonation.org/app/uploads/sites/2/2022/03/2022-RobotX_Team-Handbook_v2.pdf. [Accessed: 19-Apr-2024].