First report summary : PEGASUS01 Technical Design Paper for AUVSI SUAS 2022
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1. Requirements & Acceptance Criteria:

-Mission Setup Time: This refers to the time allocated for preparing the UAV and its systems before the mission. It involves activities such as system initialization, mission planning, and safety checks. This phase must be completed efficiently to maximize flight time.

- Flight Time: The minimum required flight duration represents the endurance of the UAV. It is critical to meet this criterion to cover the mission area effectively and accomplish all tasks.

- Waypoint Accuracy:This entails achieving precise GPS-guided navigation to designated waypoints. Ensuring high accuracy in reaching waypoints is essential for successful mission execution.

- Obstacle Avoidance: The UAV must autonomously avoid obstacles, ensuring safe navigation. The success criteria include the ability to detect obstacles in real-time and execute evasive maneuvers effectively.

- Object Detection, Classification, Localization: This involves the identification and geolocation of objects on the ground based on images captured during the mission. Accuracy in object recognition and localization is pivotal for tasks like package delivery.

- Autonomy:Autonomy refers to the UAV's ability to make decisions and navigate without human intervention during the mission. A higher level of autonomy indicates reduced reliance on human operators.

- Payload Delivery: Successful payload delivery requires precise targeting and payload release mechanisms. The criteria involve accurate payload delivery within specified zones.

- Communication: Reliable communication between the UAV, ground control station (GCS), and onboard computer is crucial. The criteria include maintaining communication links over specific frequencies and data rates.

2. System Design:

2.1 Imaging System:

- Camera Choice:The selection of the Canon EOS M6 Mark II is based on its superior features, including a high-resolution sensor, wide ISO range, and a compact form factor. These characteristics make it ideal for capturing quality images during the mission.

- On-board Processing: Real-time image processing involves onboard computational capabilities to analyze images as they are captured. It facilitates object detection, classification, and geolocation in real-time.

2.2 Object Detection, Classification, and Localization:

- Object Detection:

The object detection subsystem is crucial for identifying ground objects during the competition. The team employed a multi-stage process for object detection:

Color Separation: The UAV's camera captures images, which are then processed to separate objects based on color. This step helps distinguish objects of interest from the background.

Background Removal: An algorithm removes the background to isolate the objects. This step enhances the accuracy of subsequent object detection and classification.

Target Detection: Following background removal, the system detects potential objects within the image based on predefined shape and color characteristics.

- Object Classification:

Object classification involves determining the type or category of the detected objects. The team implemented several techniques:

Shape Identification: Objects were classified based on their shapes, such as rectangles, circles, and irregular shapes. This classification aided in identifying objects like target landing zones.

Alphanumeric Analysis: The system performed analysis on alphanumeric characters found on objects. This was vital for identifying and distinguishing objects with labels or codes.

Geolocation: For the objects identified, geolocation data was generated. The UAV's onboard GPS and IMU sensors played a pivotal role in determining the position of objects relative to the UAV's location.

- Localization:

Localization is essential for accurately determining the position of objects within the competition area. The system employed:

GPS Data: The UAV's GPS system provided its own location data, which was integrated with object geolocation to pinpoint the precise position of detected objects.

Coordinate Transformation: Geolocation data was transformed into coordinates relative to the UAV's position and orientation. This transformation ensured that objects' positions were presented in the UAV's frame of reference.

2.3 Mapping:

- Map Generation: Creating a blank map template provides a foundation for integrating geolocated objects during the mission.

- Image Preprocessing: Enhancing image quality through preprocessing techniques, such as contrast adjustment or noise reduction, improves the accuracy of object projection onto the map.

- Image Stitching: Stitching individual images onto the map template creates a comprehensive view of the mission area, enabling better situational awareness.

2.4 Air Drop:

- Mechanism: The motorized winch mechanism is designed for precise UGV (Unmanned Ground Vehicle) release. It ensures that the UGV can be deployed at a specific location during the mission.

2.5 Aircraft:

- Aircraft Configuration: The selection of a hexa-copter is based on its versatility, offering a balance between maneuverability and stability. This configuration allows the UAV to adapt to different mission requirements.

- Materials:Using carbon fiber for the airframe ensures strength while keeping the UAV lightweight, contributing to longer flight times and improved payload capacity.

2.6 Autopilot:

- Autopilot Choice:The Pixhawk 2 (CUBE) autopilot is chosen for its customizability, sensor compatibility, and reliability. It serves as the brain of the UAV, managing navigation, control, and data processing.

- Firmware: The ArduCopter firmware is the software that runs on the autopilot, providing flight control algorithms and mission planning capabilities.

- Communication: The autopilot communicates with various components, including GPS, sensors, and communication modules, to execute autonomous flight and collect data.

2.7 Communication System:

- Frequency Bands: Utilizing three radio frequencies (900 MHz, 5 GHz, 2.4 GHz) for telemetry, image transfer, RC control, and video streaming ensures robust communication across different mission-critical functions.

- Full-duplex Communication: Full-duplex communication enables simultaneous transmission and reception of data, enhancing data exchange reliability between the UAV and the ground station.

2nd report summary :

Amador Valley HS Unmanned Aerial Vehicles Team 2021-2022 AUVSI SUAS Technical Design Paper

1. Introduction

The report presents a comprehensive overview of the development and design considerations of the Amador Valley HS Unmanned Aerial Vehicles Team's UAV system, referred to as "Boreas." This UAV is primarily intended for participation in a UAS (Unmanned Aircraft System) competition.

2. Technical Details

2.1 Airframe Design

The airframe of Boreas is carefully designed to meet specific mission requirements. In response to the limitations of the conventional octocopter layout, the team opted for edge-mounted coaxial arms, significantly enhancing the central space and frame rigidity. Despite a minor efficiency loss associated with the coaxial layout, it offers substantial structural benefits, which outweigh this drawback.

2.2 Propulsion System

The choice of motors for the propulsion system is a crucial consideration. The XOAR TA6012 motor is selected for its balance of efficiency, thrust, and cost-effectiveness, aligning with budget constraints. This decision is supported by a detailed comparison of motor efficiency.

2.3 Materials

The selection of materials for various components is meticulously planned. While PLA is initially used for prototyping due to its cost-effectiveness and ease of printing, the team transitions to engineering-grade polymers like PETG and NylonX for production. These materials offer enhanced strength, temperature resistance, and durability.

2.4 ESC Mounting and Power Distribution

The positioning of Electronic Speed Controllers (ESCs) is optimized by moving them from the drone arms to the center frame. This change yields multiple advantages, including reduced weight, improved protection, and enhanced aerodynamics. The report highlights the benefits of using crimped connections for power distribution, ensuring reliability in harsh conditions.

2.5 Autopilot

The choice of an autopilot system is critical for UAV performance. The PX4 Autopilot is selected based on various criteria, including autonomous flight capabilities, simulation support, community support, licensing, and standards compliance. A detailed comparison with Ardupilot further justifies this choice.

2.6 Path Planning (Pilot)

The path planning component, Pilot, plays a pivotal role in fetching missions, constructing flight plans, and monitoring real-time progress. It is preferred over previous MAVSDK programmatic control for its simplicity and improved error detection capabilities. Pilot's Python daemon streams telemetry to Interop at a frequency of 1 Hz.

2.7 Obstacle Avoidance

Obstacle avoidance is a critical component of Boreas's functionality, ensuring safe navigation even in complex environments. The report provides a comprehensive insight into the obstacle avoidance system, highlighting its key components and decision-making process.

2.7.1 Grid-Based Approach

The obstacle avoidance system implemented in Boreas projects the flight area and identified obstacles onto a 1-meter 2D grid. This grid-based approach facilitates efficient path planning while ensuring that the drone can navigate around obstacles effectively.

2.7.2 Path Planning Algorithm - A Shortest-Path*

The core of the obstacle avoidance system relies on the A* shortest-path algorithm. This well-established algorithm is widely used for pathfinding in robotics and has proven effective in generating paths that allow the drone to traverse all waypoints while intelligently routing around obstacles.

2.7.3 Redundancy and Redundant Obstacle Clearance

To enhance safety and reliability, the system incorporates redundancy in obstacle avoidance. The report details how adjacent points along the planned path are continuously checked, and redundant points are deleted. This redundancy ensures that even if multiple points along the path fail to avoid an obstacle, the system can fall back on additional waypoints to navigate safely.

2.7.4 Real-Time Monitoring

Real-time monitoring is a crucial aspect of obstacle avoidance. As the drone progresses along its mission, the system constantly evaluates the environment, reassesses potential obstacles, and adjusts the flight path accordingly. This real-time capability is essential for handling unexpected obstacles or dynamic changes in the environment.

2.7.5 Simulation and Testing

The report emphasizes the importance of rigorous testing and simulation for the obstacle avoidance system. Prior to deployment, the system undergoes extensive testing in simulated environments, allowing the team to validate its performance under various scenarios. This testing includes scenarios with known obstacles as well as unpredictable or dynamic obstacles.

2.7.6 Safety and Reliability

Obstacle avoidance is not only about navigation but also about ensuring the safety and reliability of the UAV's missions. By employing the A* algorithm and redundancy mechanisms, Boreas aims to minimize the risk of collisions and successfully complete missions even in challenging environments.

2.7.7 Integration with Path Planner (Pilot)

The obstacle avoidance system is seamlessly integrated with the path planner component, Pilot. This integration ensures that the flight plan generated by Pilot takes obstacle avoidance into account. As a result, Boreas can navigate through its mission while avoiding obstacles efficiently.

2.8 Communications

The communication infrastructure of Boreas involves multiple radio links, each serving specific mission objectives.

2.8.1 Manual (RC) Control

For manual override in case of system failures, a Jumper T18 transmitter paired with a FrSky X8R receiver is utilized. The receiver employs frequency hopping 2.4GHz ACCST technology and connects to the Pixhawk 5X using S.BUS, ensuring reliable RC control.

2.8.2 Telemetry & Autonomous Control

Three 915 MHz RFDesign RFD900x long-range telemetry radios facilitate Point to Multipoint (P2MP) MAVLink communication between the Ground Control Station (GCS), rover, and drone. These radios offer a maximum range of 10 km and incorporate hardware-accelerated AES encryption for connection security. They are crucial for autonomous control, mission uploads, and telemetry streaming.

2.8.3 Image/Video Transfer

While the 915 MHz telemetry radio serves various communication needs, it proves inadequate for imaging tasks due to limited bandwidth. Consequently, image and video transfer rely on a 2.4 GHz WiFi system with a Ubiquiti PowerBeam directional antenna on the ground, connected to a Ubiquiti Bullet with a 12 dBi antenna. This configuration provides a robust link with approximately 100 Mbps throughput.

The transport layer for image transfer utilizes HTTP3/QUIC, which employs UDP and eliminates TCP ack/retransmit overhead. Additionally, QUIC supports a single roundtrip TLS handshake, significantly more efficient than TCP's four roundtrip handshake.

2.8.4 Antenna Tracker

A two-axis antenna tracker autonomously orients the directional PowerBeam antenna toward the UAV (Boreas). This tracker's design comprises NEMA 23 stepper motors, a 3D printed cycloidal drive, a 4-inch turntable, and spur gears. The tracker is a crucial component for maintaining a high-quality communication link with the drone, with an accuracy of within 2 degrees.

The trajectory planner, running on a Raspberry Pi 3, receives MAVLink GNSS telemetry messages and emits GCode motion commands. These commands are processed by an ATSAMD21 microcontroller, running the Klipper 3D printer firmware. Klipper provides precise acceleration control, an API (Moonraker), and a control UI (Fluidd). The tracker also incorporates an IMU to provide an absolute heading reference and compensate for uneven terrain.

3.1 Object Detection, Localization, and Classification

The Boreas UAV employs advanced computer vision techniques for object detection, localization, and classification (ODLC). This is a crucial component for various mission objectives, such as identifying and navigating to specific targets, avoiding obstacles, and performing precise actions like package delivery.

3.1.1 Object Detection Model - YOLOv5

The primary object detection model chosen for Boreas is YOLOv5 (You Only Look Once version 5). YOLOv5 is renowned for its real-time object detection capabilities and high accuracy. The report states that during testing, YOLOv5 significantly outperformed other models, including EfficientDet-D0 and conventional OpenCV Simple Blob Detection, in terms of accuracy.

3.1.2 Model Evaluation Metrics

To assess the performance of the object detection model, the team used various evaluation metrics, including:

mAP@0.5 (mean Average Precision at 0.5): This metric measures the accuracy of the model in detecting and localizing objects within a certain threshold. A higher mAP indicates better performance.

Recall: Recall measures the model's ability to correctly detect objects out of all the relevant objects present. It is an important metric for ensuring that no objects are missed.

Precision: Precision assesses the model's accuracy in classifying detected objects. It indicates how many of the detected objects are relevant.

3.1.3 Model Performance

The report provides detailed insights into the performance of the YOLOv5 model across different categories:

Pinpointing: This category focuses on precise localization of objects. The YOLOv5 model achieved a very high mAP@0.5 of 0.99, indicating excellent accuracy in pinpointing objects.

Character Recognition: In scenarios requiring the recognition of specific characters or symbols on objects, the YOLOv5 model achieved an mAP@0.5 of 0.994, demonstrating its high accuracy.

Shape Detection: Detecting and classifying objects based on their shape is another critical task. The model achieved a high mAP@0.5 of 0.987 in this category.

Orientation: Orientation detection, which assesses the alignment or angle of objects, yielded an mAP@0.5 of 0.972, indicating robust performance.

3.1.4 Real-World Testing

The report emphasizes the importance of real-world testing to validate the model's performance in practical scenarios. For this purpose, the team utilized cardboard ODLC props to mimic real-world objects. The YOLOv5 model was tested on these props to ensure satisfactory performance in detecting and localizing objects.

3.1.5 Future Improvements - Slicing Aided Hyper Inference

To further enhance object detection accuracy on real-world images, the team mentions ongoing evaluation of the "Slicing Aided Hyper Inference" method. This technique involves slicing images into smaller chunks, potentially improving accuracy, especially in complex and cluttered environments.

Report 3:
Technical Design Paper AUVSI SUAS 2022 VAMUdeS Université de Sherbrooke

Section 1: Introduction

1.1 Purpose: The document introduces the purpose of the report, which appears to be related to the development and operation of an unmanned aerial system (UAS) for a competition.
1.2 Background: It mentions that the team has used the Pixhawk 2.1 autopilot on Orion for several years, indicating continuity in UAS development.
Section 2: Technical Overview

2.1 Orion Hexacopter: Describes the UAS used for the competition, named "Orion," which is a hexacopter.
2.1.1 Dimensions: Provides the dimensions of the Orion hexacopter.
2.2 Autopilot: Discusses the use of the Pixhawk 2.1 autopilot controller for the UAS.
2.3 Tasks: Explains the three main tasks the UAS is designed to perform: obstacle avoidance, autonomous waypoint navigation, and autonomous flight.
2.4 Ground Control Station: Describes the Mission Planner software used as the ground control station and modifications made to it for competition requirements.
2.4.1 Features Added: Lists five features added to Mission Planner, including telemetry transmission, flight planning automation, obstacle avoidance, tracking antenna integration, and safety features.
2.5 PID Controllers: Confirms that the PID controllers have remained unchanged as they are well-calibrated.

2.6 Obstacle Avoidance: Explains the obstacle avoidance algorithm used, which calculates new waypoints to navigate around stationary obstacles.

2.7 Object Detection:
Object detection is a crucial component in UAS systems, especially for tasks like obstacle avoidance and target identification. The report does mention the use of an obstacle avoidance algorithm, but it does not provide specific details. Common object detection techniques include:

2.7.1.1 Computer Vision: Traditional computer vision techniques involve the use of cameras and image processing algorithms to detect objects. Features like edges, colors, and shapes are used to identify objects.

2.7.1.2 Deep Learning: Convolutional Neural Networks (CNNs) have revolutionized object detection. Methods like Single Shot MultiBox Detector (SSD) and You Only Look Once (YOLO) are popular choices for real-time object detection.

2.7.1.3 LiDAR: Light Detection and Ranging (LiDAR) sensors emit laser beams to measure distances to objects. LiDAR data is used to create 3D point clouds, which can be analyzed to detect obstacles.

2.7.2 Classification:
Classification involves categorizing detected objects into predefined classes or categories. This is crucial for tasks like identifying specific targets or distinguishing between obstacles and non-obstacles. Common classification methods include:

2.7.2.1 Machine Learning: Supervised machine learning algorithms can be trained on labeled data to classify objects. Random Forest, Support Vector Machines (SVM), and neural networks are commonly used.

2.7.2.2 Deep Learning: CNNs can not only detect objects but also classify them. Transfer learning, where pre-trained models are fine-tuned for specific classes, is often employed.

2.7.2.3 Feature Extraction: Handcrafted features like Histogram of Oriented Gradients (HOG) or Local Binary Patterns (LBP) can be used for object classification.

2.7.2.4 Sensor Fusion: Combining information from multiple sensors, such as cameras and LiDAR, can improve classification accuracy.

2.8 Communications: Describes the communication systems used for various purposes, including safety pilot communication, autopilot communication, payload communication, and UGV communication

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2.8.1 Safety Pilot Communication: Discusses the 2.4 GHz link used for pilot-UAV communication.

2.8.2 Autopilot Communication: Details the use of RFD900+ radios for ground control station communication with the UAV.

2.8.3 Payload Communication: Explains the use of directional antennas and a high-bandwidth link for payload control and data transfer.

2.8.4 UGV Communication: Discusses the use of 915 MHz radios for UGV control and monitoring.

4.1 Developmental testing: Discusses testing of various components, including new ones, to ensure they meet safety and functionality standards.
4.2 Mission Testing: Explains the importance of mission simulations to prepare the team for the competition. Describes ground and air simulations and the use of checklists and procedures.
Section 5: Safety, Risks & Mitigations

5.1 Developmental Risks & Mitigations: Addresses risks associated with UAS development and the mitigation measures in place.
5.2 Mission Risks & Mitigations: Discusses risks associated with UAS operation during missions and the strategies used to mitigate them, such as temperature extremes, pilot errors, incomplete preparations, propeller safety, battery fire, heatstroke, and drone collisions.