Aerial Manipulator

final year project feasibility study by group 26

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Aerial Manipulator

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Aerial Manipulator

Introduction

An aerial manipulator is a robotic system that combines the capabilities of an unmanned aerial vehicle (UAV) or drone with a robotic arm or manipulator. This combination allows the UAV to perform tasks that require both flying and manipulation of objects or the environment.

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Our project integrates a three-link robot arm with a multirotor, enhancing it with RTK GPS and Raspberry Pi vision for autonomous object manipulation.

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Primary Objectives

- Design and build a multirotor UAV (Unmanned Aerial Vehicle) equipped with a three-link robotic arm.
- Enable aerial manipulation capabilities for the UAV to interact with objects in the environment.
- Develop precise control algorithms and systems to execute aerial object manipulation tasks.
- Address challenges related to stability, control, and object recognition for safe and efficient operations.

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Scope of the project

- Design and build a secure three-link robot arm for multirotor integration.
- Integrate RTK GPS to enhance location accuracy for precise navigation.
- Implement computer vision algorithms on Raspberry Pi for object detection.
- Develop autonomous control algorithms for multirotor and robot arm.
- Conduct experimental tests to evaluate accuracy, stability, power consumption, and object grasping success.

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Modern Drone System

UAV System

Flight Controller Software

Flight controller software is the brain of the drone, responsible for controlling its flight parameters, stability, and navigation

It includes algorithms and control loops that process sensor data (e.g., accelerometers, gyroscopes, GPS, barometers) to maintain stability and execute flight commands.

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Flight Controller Hardware

Flight controller hardware refers to the physical electronic component that runs the flight controller software.

Sensors, like accelerometers, gyroscopes, magnetometers, barometers, and GPS modules, provide data necessary for flight control and navigation.

Drone Hardware Components

Drone hardware encompasses all the physical components of the drone, including the frame, motors, propellers, battery, camera (if applicable), and other peripherals

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Literature Review

Flight Control Software | ArduPilot

- ArduPilot is a full-featured autopilot based on the open-source Arduino platform [2]
- Supports various vehicle types: drones, helicopters, boats, and more.[3]
- Ardupilot uses advanced kalman filter to fuse myriad of sensors inputs into one altitude/ position estimation.[4]

[2] The design of an unmanned aerial vehicle based on the ArduPilot | He Bin and Amahah Justice | Beijing University of Chemical Technology, Beijing, China-100029
[3] ardupilot.com
[4[Wu, Y., Sui, Y., Wang, G.: Vision-based real-time aerial object localization and tracking for UAV sensing system. IEEE Access 5, 23969–23978 (2017)

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Literature Review

Flight Controller Hardware | Pixhawk

- Pixhawk is a miniaturized, open-source autopilot system for various aircraft types.[5]
- It supports fixed-wing, multi-rotor, and rotor-craft vehicles.[6]
- Developed to be cost-effective, powerful, and user-friendly.[7]
- Built-in support for GPS, telemetry, sensors,wifi and peripherals.[8]

[5][6][7][8] https://pixhawk.org/
PIXHAWK: A system for autonomous flight using onboard computer vision

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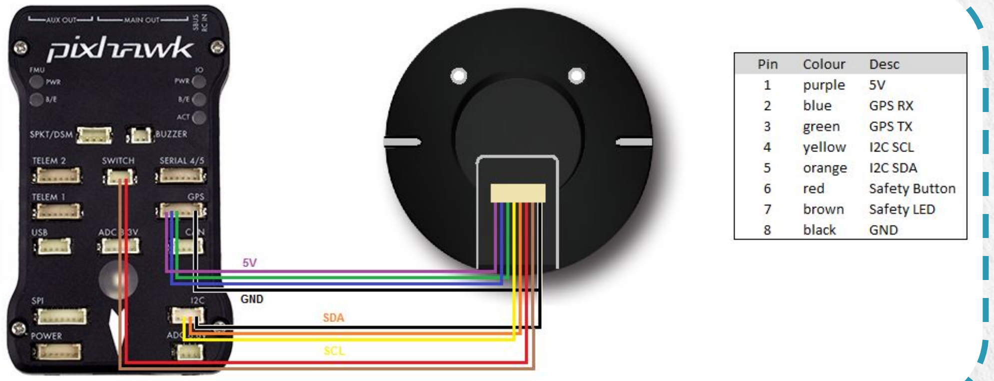
Literature Review

Drone Hardware | RTK GPS

- RTK GPS is a high-precision satellite navigation technique that provides centimeter-level accuracy in real-time[9]
- RTK GPS involves a base station with a known location and an RTK GPS receiver on the moving vehicle



[9] RTK GPS by Richard B Langley | University of new brunswick

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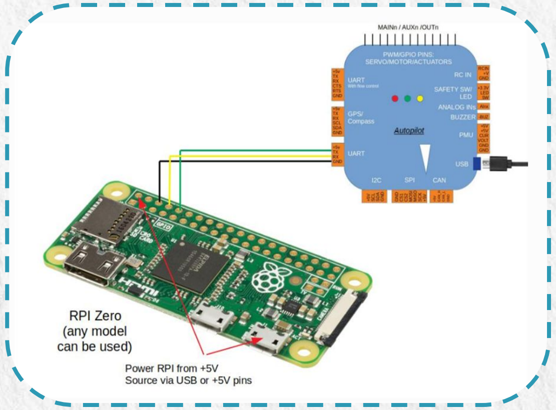
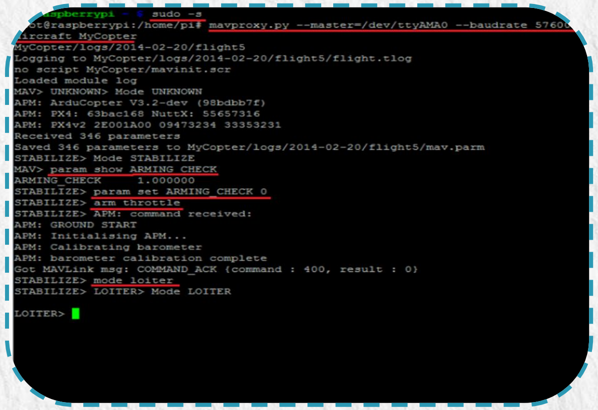
Literature Review

Drone Hardware | Raspberry Pi

Raspberry Pi (RPi) can establish communication with a flight controller by utilizing the MAVLink protocol through a serial connection (TELEM2 port) [10]

The Pixhawk can send telemetry data (e.g., GPS coordinates, altitude) to the Raspberry Pi, allowing it to make navigation decisions based on object detection results.





[10] Communicating with Raspberry Pi via MAVLink by Saif Aldeen Saad Alkadhim Xi'an Jiaotong University (XJTU) - State Key Laboratory of Electrical Insulation and Power Equipment

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Robotic Arm

(a) Quadrotor is approaching the designated position

(b) Robot arm is grabbing the wood block

(c) The wood block is picked up and quadrotor moves to the next position

Fig. 8: Pictures taken during pick-up phase

Source : Aerial Manipulation Using a Quadrotor with a Two DOF Robotic Arm (2013)
by **Suseong Kim , Seungwon Choi and H. Jin Kim**

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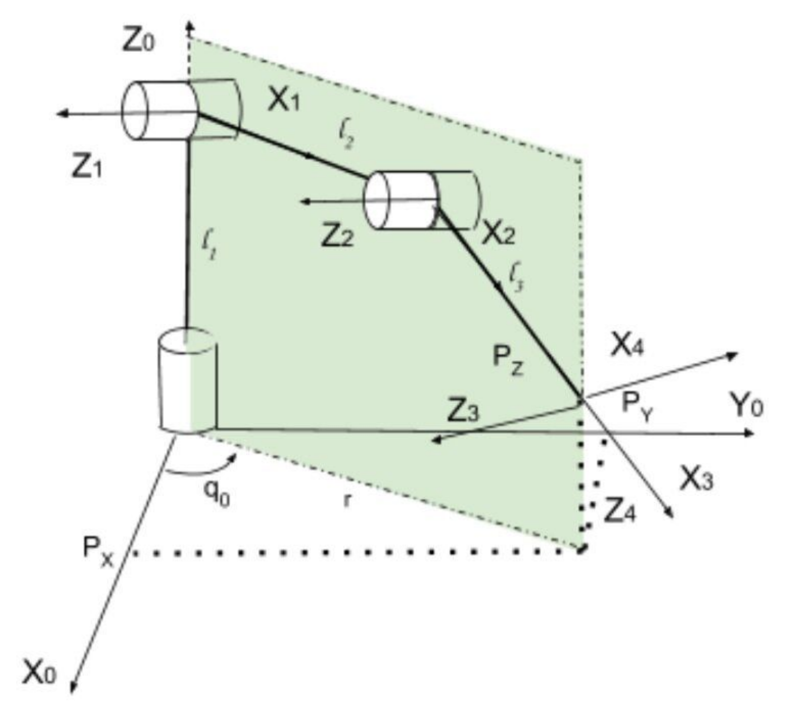
Robotic Arm

- 3 DOF robotic arm with 2 joints.
- Rotation about the base, 2 revolute joints
- Two finger Gripper



required torque for firsts motor = 3.65kg/cm
motor = towerpro servo sg5010

required torque for second motor = 9.2kg/cm
motor = towerpro servo mg995

Source: https://www.nickbenoit.me/three-dof-robotic-arm

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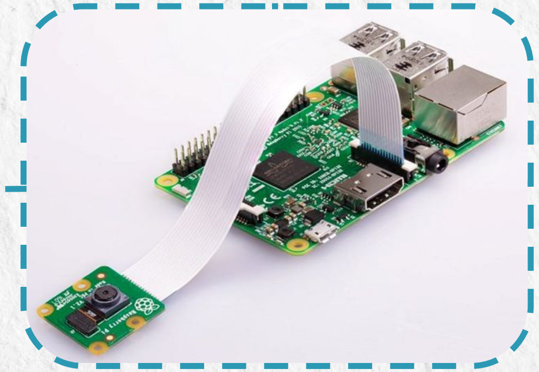
Object Detection

Object Detection Criteria

Our objective is to detect objects based on their **color, shape, size, and edges.**

Object Distance Measurement

Once successful object detection is achieved, we proceed to measure the distance between the object and the Raspberry Pi camera and the width of the object. After using these to calculate the focal length of the camera. (**F = (P X D) / W**) Then we used that focal length to determine the object distance with the help of the triangle similarity method. For object distance detection also we plan to use OpenCV algorithms.



Detection Methods

To achieve this, we utilize computer vision algorithms from OpenCV.
In scenarios involving edge detection, we employ image processing techniques, specifically the Canny edge detection method.

Calibration for Precision

Throughout the process, we meticulously apply calibration steps to uniquely identify our target objects.
We also employ these calibrations to guide our aerial drone to a precise height and facilitate object retrieval via Raspberry Pi.

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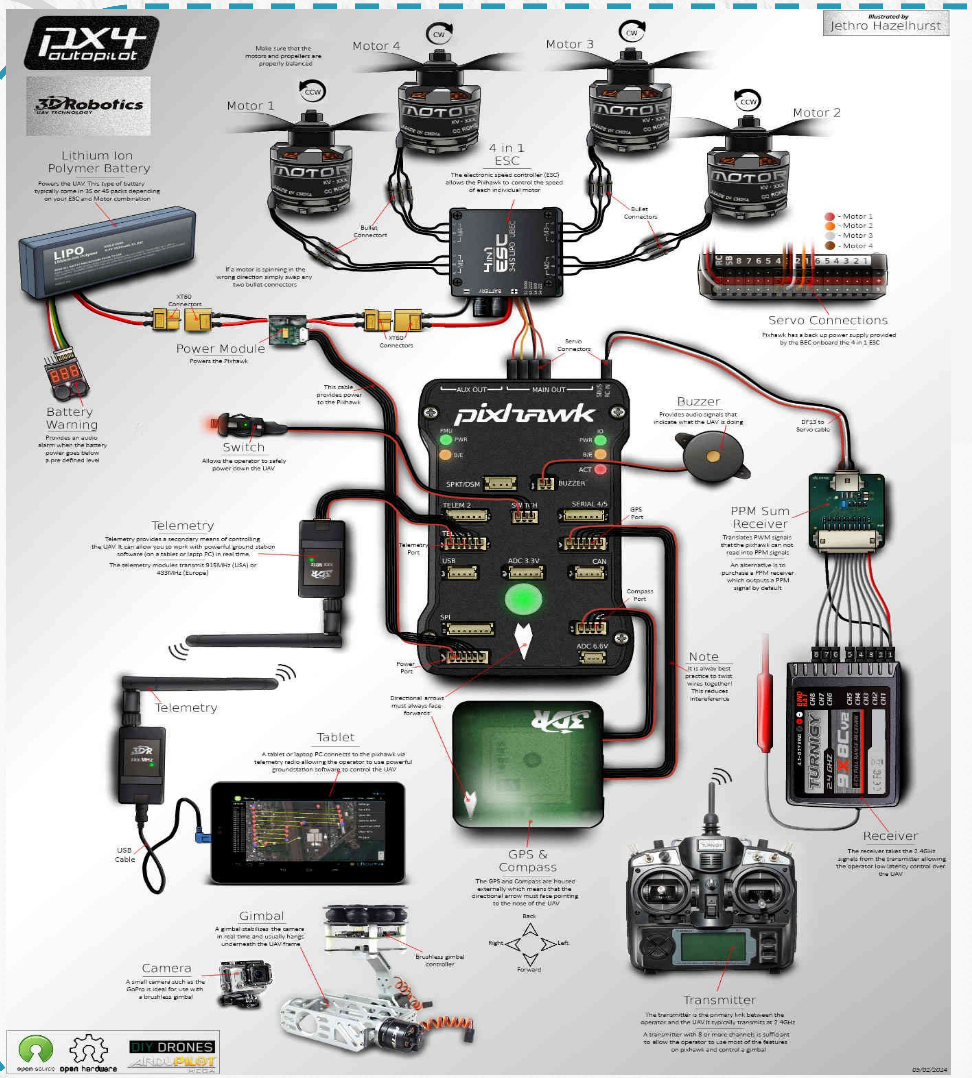
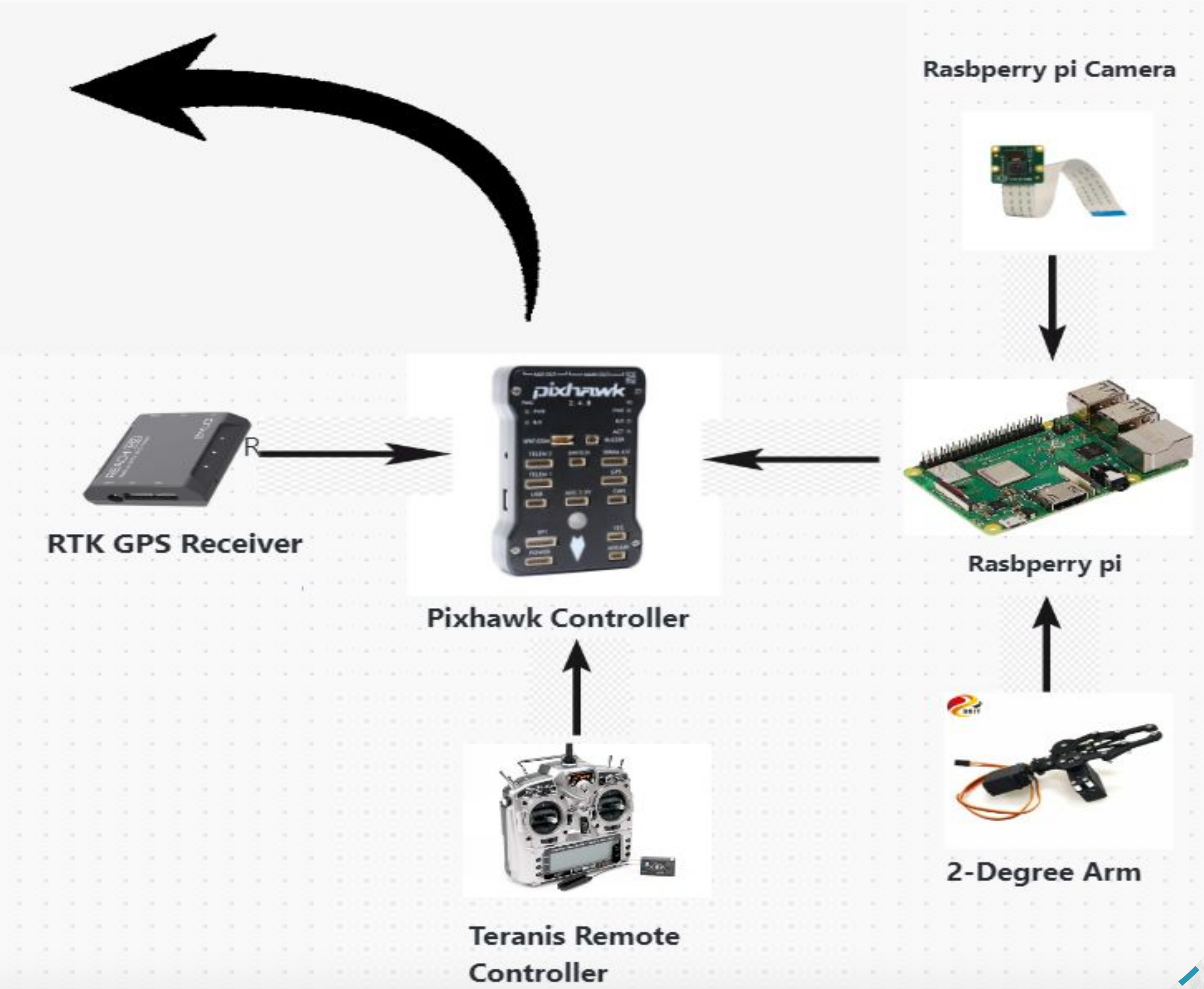
System Overview





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Financial & Social Aspects

Growing Interest

UAVs have gained increasing attention from research communities, industries, and the public in the last decade.

Notable examples include e-commerce companies exploring UAVs for package delivery and government funding for UAV research in various civilian domains.

Expanding Applications

UAV applications extend to diverse fields, including disaster response, infrastructure monitoring, archaeology, and personal use.

UAVs offer the potential for safer and more cost-effective solutions in various industrial and service applications.

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Potential Use Cases

Aerial Inspection and Surveillance

Aerial manipulators can perform detailed inspections of infrastructure, pipelines, and remote areas, enhancing safety and reducing maintenance costs.

Search and Rescue operations

Rapid deployment of aerial manipulators aids in locating and rescuing individuals in emergency situations, such as natural disasters or accidents.

Environmental Monitoring

Utilize aerial manipulators for environmental research, wildlife tracking, and monitoring of ecological changes.

Agricultural Precision

Aerial manipulators offer precision agriculture solutions for crop monitoring, pesticide application, and yield optimization.

Infrastructure Maintenance

Streamline infrastructure maintenance by using aerial manipulators to inspect and repair structures such as bridges, power lines, and wind turbines.

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Risk Factors

Financial Risks

- Budget overruns due to unforeseen expenses, including potential damages from crashes.
- Funding uncertainties or delays in securing project resources.

Technical Risks

- ration complexities between the quadrotor, robot arm, and vision system.
- Software and hardware compatibility issues.
- Technical failures during experimental testing.

Risk Mitigation

- Develop a comprehensive risk mitigation plan.
- Continuous monitoring and adaptation to minimize potential setbacks.
- Implement thorough testing protocols to reduce the risk of crashes during experimentation, considering the constraints of available environments.

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Task Delegation

Subsystem	Person in Charge
Vision System	Luxshan
Manipulator	Loshanan
Drone, Electronics and Mechanical subsystem	Ramila
Communications & GPS	Aakkash

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Project Budget

Item/Expense Category	Estimated Cost	Procurement Status
BLDC Motors	Rs.60000	Available
ESCs	Rs.18000	Available
Pixhawk Flight Controller	Rs.50000	Available
Raspberry Pi	Rs.20000	Available
Raspberry Pi camera module	Rs.2500	Available
Li-po Battery	Rs.10000	To Be Procured
Carbon Fiber Tubes	Rs.10000	To Be Procured
Total	Rs.170500	

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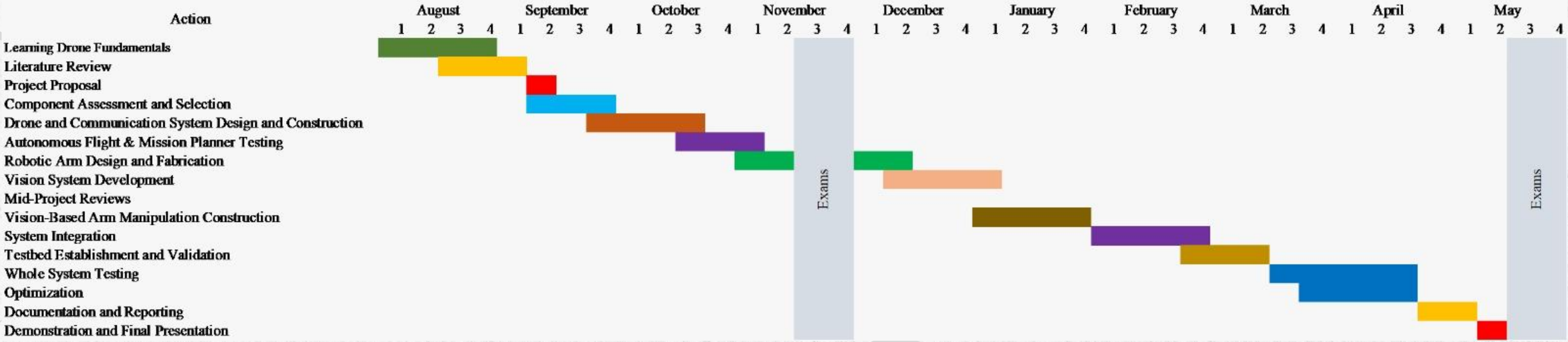
Project Timeline



Thank You

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