INTER IIT
TECH MEET 13.0

HIGH PREP

ideaForge™
Create. Inspire

POSITION AND ALTITUDE CONTROL OF QUADROTOR WITH SINGLE MOTOR FAILURE

About ideaForge

At the forefront of cutting-edge drone technology, with a focus on developing superior solutions for intelligence, surveillance, and reconnaissance (ISR) purposes, ideaForge has its origins over 17 years ago. The company is built with a mission to develop technically superior UAVs for various missions, utilizing modern advancements in aerospace and robotics. From being a humble start-up, now ideaForge Technology has recently offered its IPO and become a listed company in NSE and BSE.

ideaForge is a vertically integrated company with an in-house product development centre, allowing us to design, develop, engineer, and manufacture indigenous unmanned aerial vehicles (UAVs). ideaForge was founded in 2007, and over time became the pioneer and pre-eminent market leader in the Indian unmanned aircraft systems ("UAS") market. ideaForge had the largest operational deployment of indigenous UAVs across India, with an ideaForge manufactured drone taking off every four minutes on average for surveillance and mapping. As of today, their customers have completed over 500,000 flights using our UAVs.

ideaForge UAVs are equipped with industry-leading specifications and capabilities, comparable to those of other established global players in the UAV industry. Their in-house design, development, engineering, and manufacturing capabilities have enabled us to develop better products in response to changing customer demands, thereby improving customer experience with our products. The company serves domestic and international customers in the defense and civil sectors, primarily for surveillance, mapping, and surveying applications. Our customers include the Indian Armed Forces, homeland security authorities comprising certain central armed police forces, state police departments, disaster management forces, forest departments, government along with private entities, enterprise sectors and many more.

The company is closely working with the Indian Armed Forces for the deployment of their drones for important security and surveillance missions. ideaForge UAVs are deployed across Indian borders, assisting the Indian Army in surveillance and secure the nation.

Furthermore, several Police Departments, Government and private authorities have deployed the ideaForge UAVs for a variety of surveillance, mapping, and surveying operations such as anti-terror, anti-Naxal operations, illegal activity prevention, crime control, traffic monitoring, mine area planning, volumetric estimations, land survey and many others.

Introduction & Motivation

Quadrotors are a popular choice for small UAVs due to multiple reasons. First, they have a fairly straightforward design. Second, their symmetric design simplifies the control algorithms needed to operate these UAVs and provides inherent stability. Their capabilities like vertical takeoff and landing (VTOL), stable hover allow space efficient deployment and maneuverability. Quadrotor based UAVs are widely used today across multiple applications including aerial surveillance, surveying and mapping, inspection, aerial photography, search and rescue, agriculture, delivery logistics, etc.

However, the simple and minimal design of quadrotors also makes them vulnerable to the failure of a single motor, which can lead to loss of control and potential crashes. Motor failure could occur due to mechanical causes such as bearing, shaft or propeller issues, or electrical causes such as overheating, short circuits, winding damage, etc. Operating in extreme environmental conditions such as heat, cold or rain can also lead to failure.

As UAV platforms increase in size and weight and as the deployment of UAVs in urban, populated areas keeps growing, any potential UAV crash can cause harm to human life or property. Developing a robust control algorithm to handle motor failures is therefore crucial for enhancing the safety and reliability of quadrotor systems.

Problem Statement

Given the potential damage that a UAV crash due to a single motor failure can cause, the problem is to design and implement a control algorithm that enables a standard quadrotor to recover with minimum loss of stability in the event of a single motor failure. Solutions could iteratively build on smaller sub-problems of increasing complexity

- Implicit detection of single motor failure
- Control adjustments to remaining three motors for an immediate controlled landing (for example spinning and landing)
- Control adjustments to remaining three motors to achieve stable hover (altitude and position hold)
- Control adjustments to remaining three motors to achieve basic navigation and altitude control to allow safe return home / landing

System Setup

The solution should be designed in the context of the following system configuration:

- Standard quadrotor configuration
- Onboard sensors may include Accelerometer, Gyroscope, Magnetometer, Barometer and GPS. No additional sensors should be assumed
- No reversible motor/prop or tilt/servo mechanisms
- All solutions must be developed using the open source PX4 flight controller stack
- Teams should use the Gazebo simulator using the IRIS model (default gazebo quadrotor model)
- Teams able to achieve a successful simulation can attempt to demonstrate the solution in an actual flight for bonus points – links to the PX4 compatible development kits are given below.

Solution Deliverables

- A report outlining the control algorithm used along with any assumptions, calculations, technical references, simulation results, flight results (if available) and any other relevant technical details to assess the correctness of the solution
- Working code with proper comments/documentation that should be easy to compile and deploy on a PX4 based quadcopter platform
- **Mandatory**: Simulation videos & Live Simulator Demonstration showing the working of the final implemented solution
- **Bonus Points** will be awarded for physical demonstration of the solution in a low altitude free flight using one of the PX4 based development kits as listed below

Evaluation Parameters

As stated earlier, the recovery from a single motor failure in a UAV could be designed at various complexity levels. Points awarded while judging the solutions will therefore also increase progressively with the complexity of the achieved solution.

Motor failure detection (Max 20% of total points): a working solution must be able to implicitly detect the failure of a single motor. Key metrics for failure detection include missed / false detections and the latency of detection.

Upon detecting the failure, the system should adjust the control inputs to the remaining three motors to achieve the possible degree of control. The points awarded at this step will depend on the degree to which the quadrotor is able to achieve somewhat stabilized control. The highest level of complexity achieved would be considered while scoring

Controlled Landing (Max 20% of total points): The basic recovery solution where the UAV performs an immediate controlled landing will be assessed based on the landing parameters such as tilt angle, speed and stability of landing, etc.

OR

Stable Hover (Max 40% of total points): Solutions where the UAV can achieve a stable position and altitude hold (hover) will be rated higher than ones achieving immediate controlled landing.

OR

Stable Hover + Return Home and Land (Max 60% of total points): Likewise the solutions which achieve stable hover and subsequently also allow for basic navigation of the UAV so as to return home and land safely will be rated the highest.

If some team(s) are able to solve and demonstrate the working solution up to a certain stage in the Gazebo simulations, they may attempt to implement the same on an actual UAV hardware platform built using the recommended PX4 development kit for additional bonus points. It should be noted that the hardware implementation and flight demonstration is not mandatory but the teams' choice depending on the progress made in simulation and the willingness of the participants.

The bonus points for the actual flight will also be awarded in proportion to the complexity of the solution. For instance, a solution that can demonstrate failure detection only, in simulation and live flight will not be rated higher than a solution that works only in simulation but enables the aircraft to hover, return home, and land safely (**maximum 1.5x of simulation points**)

Additional points will also be granted based on the technical report, code quality and easy deployability of the code on PX4 platforms. (**Max 20% of total points**)

Project Timelines

• **Mid-term**: After completion of Week 4, the teams shall submit report with their overall approach outline, background study and analysis, experimental results and any simulation data or videos. During this review, the company representatives may also request for additional documents or suggest additional testing to be carried out (**Weightage: 30%**)

• **Final presentation and demo**: At the end, the participating teams will submit their final deliverables as stated earlier and will also have a live demonstration either in simulator or live flight + a Q&A session with the company representatives. (**Weightage: 70%**)

Resources

1. PX4 Autopilot: https://docs.px4.io/main/en/index.html
2. Gazebo Simulator: https://docs.px4.io/main/en/sim_gazebo_gz/
3. Simulating motor failure in Gazebo: https://discuss.px4.io/t/using-gazebo-motor-failure-pluginin-gazebo-simulation/18807

https://www.youtube.com/watch?v=yR5okaHITpg

4. PX4 compatible UAV kits: https://docs.px4.io/main/en/frames_multicopter/kits.html
5. Multicopter Attitude Controller, mixer https://docs.px4.io/main/en/modules/modules_controller.html#mc-att-control