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Research on UAV Technology

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Development of Small Sized Fixed Wing Unmanned Aerial System

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Sponsor: IIT Kanpur and Prabhu Goel Foundation

Product Characteristics

- Easy to assemble – modular approach, can be carried on the back of a Jeep or Gypsy
- Short take-off and landing: approximately 50 feet of flat surface as runway
- Autonomous flight capability – controlled by on-board autopilot, allows for multiple flight modes
- Navigation and Flight modes: GPS based Waypoint navigation as well as loitering flight mode for target tracking
- Payloads: Multiple surveillance and environmental sensing payloads. Example: EO camera, IR camera, Dual, Aerosol sensors, CO_2 sensors, etc.
- Maximum Take Off Weight (MTOW): 16 to 21 kg
- Propulsion: Electric or Gasoline based on mission requirements
- Endurance (continuous flight): 4 hours to 10 h
- Wingspan: 3 – 3.6 m
- Length: 2 - 2.30 m
- Redundant communication systems for telemetry and data.
- Time to assemble the system: approximately 20 min
- Cruise speeds: 55 - 120 kmph

The project aimed at developing a small sized Unmanned Aerial System (UAS) based on the fixed wing platform, having long endurance, in a pusher configuration; capable of both civil and defense applications. The platform was chosen specifically to accommodate future modifications to the design; larger wingspan and heavier payloads.

The developed UAS has long endurance - greater than seven hours, and good all-up weight - about 16 - 21 kilograms, in which payload capacity varies from 2-6 kilograms. The UAS propulsion system can be either electrical or gasoline, both mounted in a pusher configuration. The pusher configuration was chosen keeping in mind futuristic application of the UAS in sensitive areas where exhaust fumes from puller engine may affect different environmental sensors. Our UAS is presently operated through a Ground Control System (GCS), with autonomous flight capability using an on-board autopilot that is capable of waypoint navigation and loitering flight; except take-off and landing. The present system is designed and tested for an operational ceiling of 5000 feet from the sea level.

After analysing the defense and civil scenario, it is identified that the low altitude long endurance tactical section of UAV is the most lacking area. Such UAVs find application in border patrol, search and rescue, traffic monitoring, crowd control, environmental studies, asset monitoring, crop monitoring and re-supply.

Initially, multiple configurations were designed and tested for attaining the design specifications. The most important of them were the wing loading and power loading, which was extensively studied. The results are summarized in Figure 1.

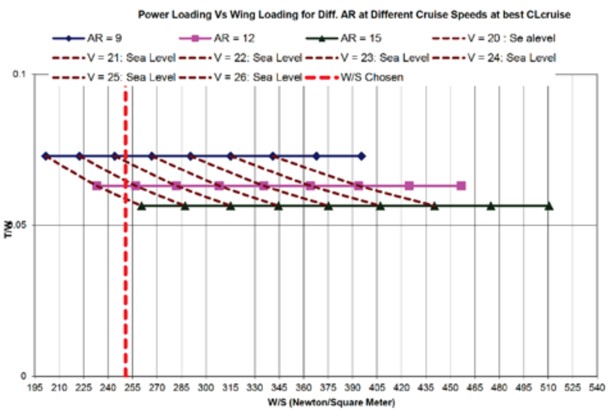

Figure 1: Power loading vs Wing loading graph

Once the airframe design was finalized, the manufacturing of the airframe was researched for rapid production, maintainability, knock-down for easy transportation to mission locations, repairability, along with rapid instrumentation for conversion to a research platform. Considering all aspects, we decided to use composites, mainly of fibre reinforced plastics, Kevlar, and carbon fibre. For example, the fuselage was made as hollow monocoque structure, made of fibreglass sandwiched with 2 mm rohacell. Similar approach was also used for wing manufacturing, where the final surface finish met the aerospace requirements, as shown in Figure 2.

Figure 2: Wing part developed using the manufacturing process

The control system provides integrated miniaturized avionics for autonomous control of micro/mini UAV, which is also capable of automatic take-off, landing, waypoint navigation and steering flight control with manual override. The MIL grade autopilot has integrated INS/GPS and Air data System provide accurate estimates of altitude, velocity and position. The versatile I/O interface provides option to hook up external payloads for user specific requirement. The integrated datalink modem provides communication in excess of 20 kms range. Users can dynamically plan mission, monitor critical flight parameters and adjust UAV parameters through an intuitive graphical user interface (GUI). The system performance was characterized and typical outcome is shown in Figure 3.

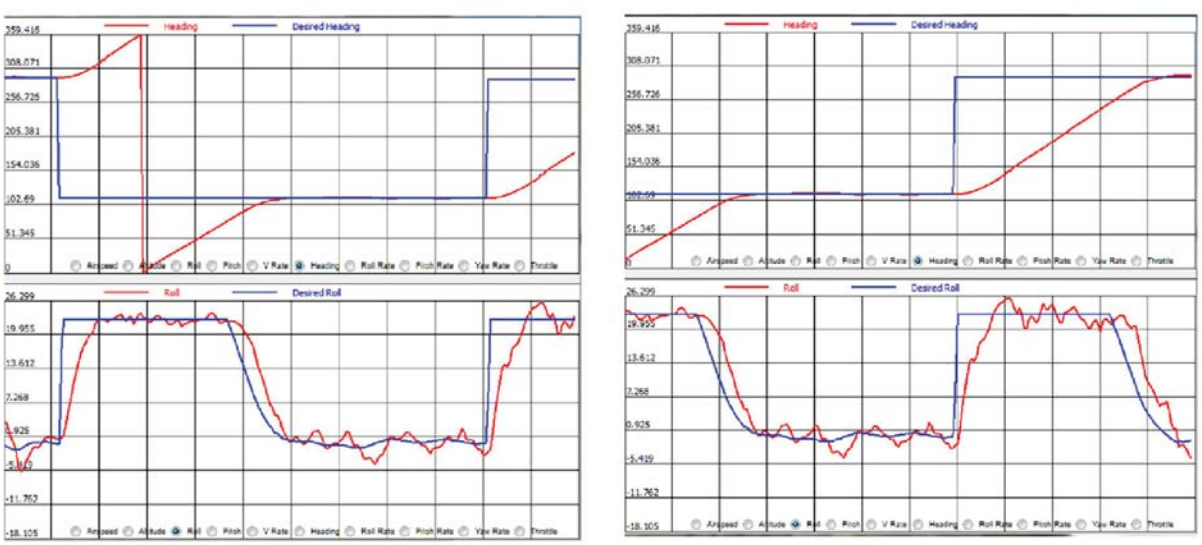

Figure 3: Heading hold and step commands and performance of roll

Design and Fabrication of Autonomous Flapping Wing Unmanned Air Vehicle for Surveillance and Aerial Photography

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Sponsor: IIT Kanpur and Prabhu Goel Foundation

Specific Objective

- Design and fabrication of an autonomous flapping wing UAV of 1.5m wing span with endurance of 60mins
- Making it autonomous in a communication range of 2km with a image capture and communication module on the airborne platform
- A ground based module that receives the UAV data, processes it, registers the data against the map database.
- Image stabilization

Model specifications:

- Wingspan 1.6m
- Dry Weight: 400 g
- Endurance: more than 1 hour with 2 batteries (1000mAh each 3 cell)
- Cruise speed: 6 to 8 m/s
- Stiffness: Mylar and LDPE tubes

The project aims to build an autonomous 1.5 m wing span flying bird which will carry a small camera as the payload and will be able to record pictures for surveillance applications. Two other flying models have been constructed of wind span 1.6m with very distinct mechanisms and weight. The use of polythene wing membrane with density 40gm/m^2 has proved to deliver superior performance.

Technical Results Obtained:

Flapping wing vehicle:

- Two new flying models have been constructed of wingspan 1.6m each with different mechanism and weight.
- Various materials were tested for a good wing construction and different arrangements of stiffeners.
- Polythene wing membrane (40 grams /sqm) proved to deliver superior performance than a polyurethane coated nylon fabric (80 grams /sqm)
- Density of the wing membrane is critically important and plays a vital role in the flight performance. The nature of flexibility for the large wing needs to be investigated.
- Wind tunnel testing has been carried on a smaller model of 1 m wingspan (Cleo) using ATI mini 40 6axis load cell at NWTF.

Autonomous flight test carried out on this model for loiter mode:

- Flight data (Euler angles and rates) are collected using a NAVSTIK autopilot with onboard data logging.
- Unlike an aircraft, the attitude of ornithopter contains ripples of oscillations which has same frequency as the flapping of the wings and is filtered using a low pass filter to get the attitude of the vehicle.
- The tail movement generates a coupling between pitch and yaw. To decouple, a mixing is introduced in the tail i.e. when the tail turns to yaw, it also pitches up to compensate for the effective reduction of tail area due to turning.
- The vehicle is further tuned manually by adjusting gains of the autopilot by flying and testing.
- Loiter is accomplished by flying in a circle of given radius.
- Once properly tuned the vehicle was able to fly through the specified path.

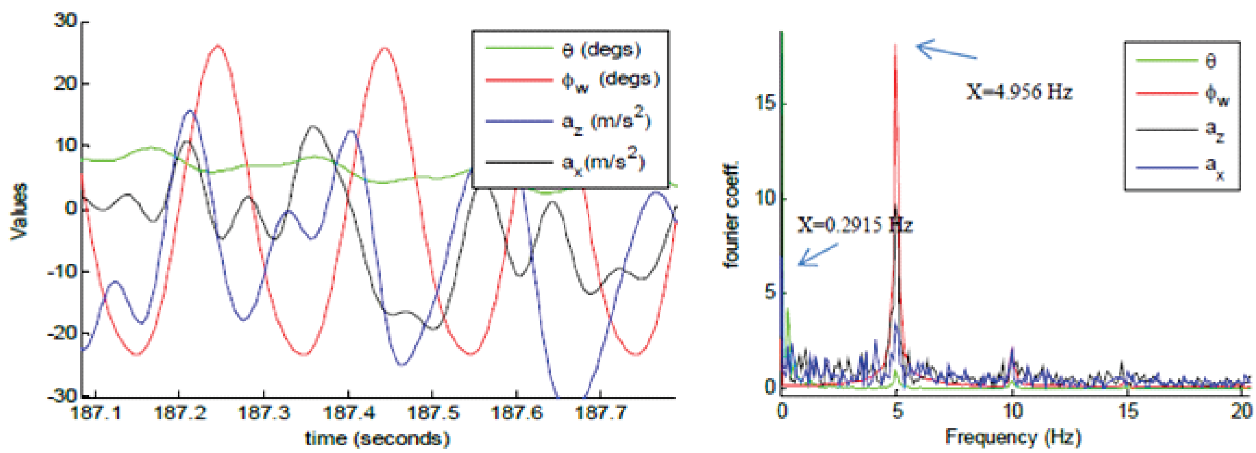


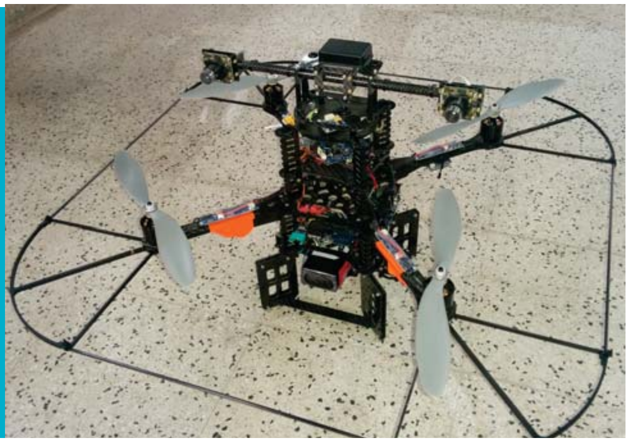
Figure : (a) In flight filtered pitch angle, wing position and accelerations raw data from IMU for the ornithopter Cleo acquired at 200 Hz (b) Fourier coefficients of pitch angle, wing position acceleration. Here flapping frequency is 4.956Hz and pitching heaving oscillations are strongly correlated to this frequency. X=0.2915Hz is the phugoid or long period frequency during flight.

Requirements:

- For the estimation of inertial force of the wings a vacuum chamber of 2 x $2m^2$ is required.

- A testing facility (an open jet low speed wind tunnel of 3 x $3m^2$ cross section and maximum wind speed of 20-30m/s) for larger models is required to be created. The facility should consist of force measurement devises along with gust generation mechanisms. This can also be used as low speed wind tunnel which finds many applications in the field of aerospace engineering.

Design and Development of Visually Guided Autonomous Quadrotors: application in surveillance and disaster management



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Specific Objective

- Development of a Visually Guided Quadrotor
  - Visual Control
  - VSLAM
  - Trajectory Planner
- Stabilizing Controllers
  - Backstepping
  - Sliding Mode
  - Fuzzy Control
- Formation Control – Theoretical Developments
- Demonstration of Quadrotor formation

The need for unmanned aerial vehicles (UAVs) with greater maneuverability and hovering ability for various military and civilian applications has led to the current rise in quadrotor research. A quadrotor, also called a quadrotor helicopter or quad copter, is a multi-copter that is lifted and propelled by four rotors. The four-rotor design allows quadrotors to be relatively simple in design yet highly reliable, agile and maneuverable.

Development of a Visually Guided Quadrotor

The concept of Localization is used for maintaining the quadrotor at a particular point in 3D space. In Figure 1, we demonstrate visual control of a quadrotor (Pelican from AscTec) for hovering at a specific altitude where the current position is obtained by looking at a predefined pattern present on the ground. The control architecture is shown in Figure 2.

A very real life application of this experiment lies in rescue operations during the event of an environmental disaster. A quadrotor can enter a damaged building and move to places which would otherwise be difficult to access by rescue teams.

Figure 1: A quodrotor is hoovering based on visual feedback

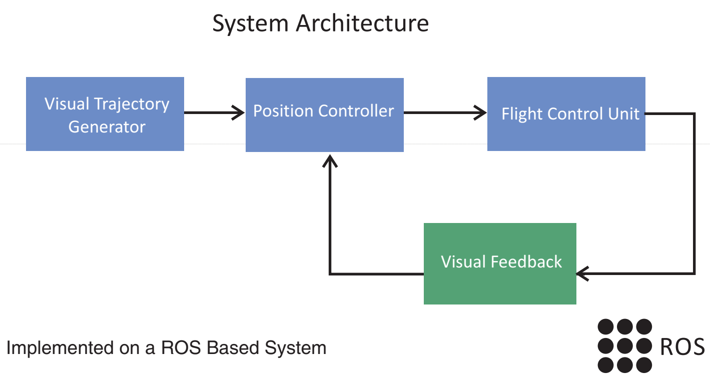

Figure 2: System architecture for Vision Based Navigation

Visual Navigation of a Quadrotor

Single camera is used to reduce the payload and increase the endurance of the system. The two frames, displaced in time, are taken to simulate the stereo vision for computing the depth of the target/scene. To calculate the correspondence between two frames, feature points detected from the images are matched. We can calculate the disparity between matched points caused by UAV movement by taking the difference between the two coordinate positions in the scenes. Since the UAV can also undergo rotation, we compensate for disparity caused by rotation. The scheme is provided in Figure 3.

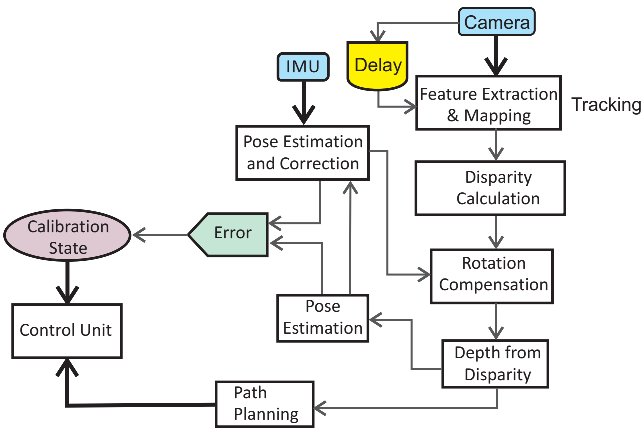

Figure 3: Proposed Visual Navigation Scheme

Stabilization of Multi-UAV systems and Formation Control

Formation of quadrotors has great applications in precision agriculture, disaster management and crowd control. We consider an n-agent system where the agents move on a plane. Each agent communicates with its neighbours. The communication topology is fixed and is represented by a completely connected graph G. The objective of this work is to develop a control law to achieve a desired formation. The control law comprises of two parts: Improve collision avoidance scheme (ICAS) and consensus term. The ICAS has been designed to avoid collision between agents, and the consensus term helps in achieving the desired formation.

We consider a 6-agent system to generate the collision free desired hexagon formation. Figure-4 is presented the trajectories of the six agents and from figure 5 it is observed that no agents collide with each other as the minimum inter agent distances never goes less than the safety distance r_{in}=0.5.

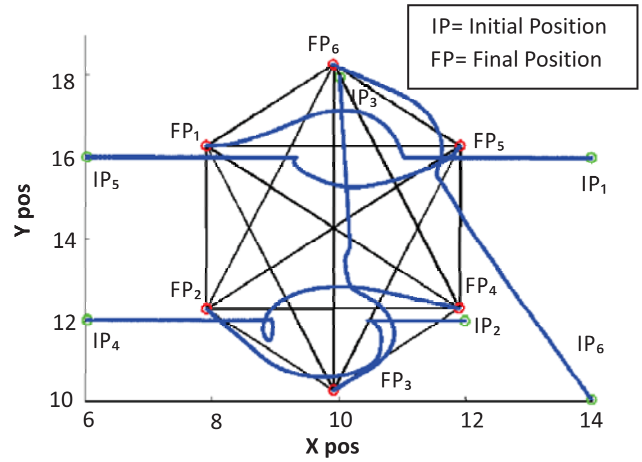

Figure 4: Six agents make a formation

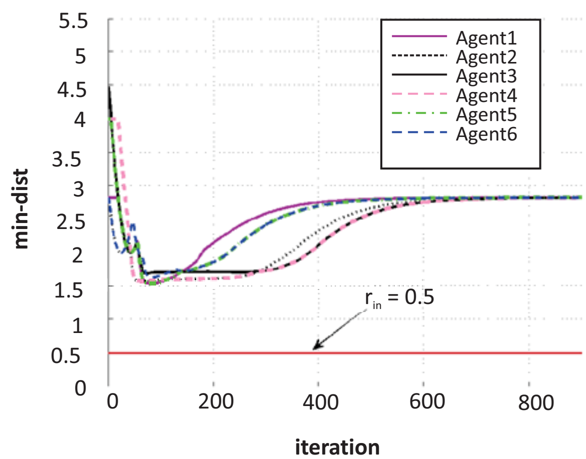

Figure 5: There is no collision during the formation

Static and Dynamic Boundary Estimation and Tracking:

We consider 2n-agent system where the agents move on a plane. Each ith agent can communicate with its two neighbouring agents (Backward and Forward agents). The communication topology is fixed and is represented by a connected graph G. Each i^{th} actual agent is associated with $(i+1)^{th}$ virtual agent (odd index is for actual agents and even index is for the corresponding virtual agent). The objective of this work is to develop a boundary tracking and estimation algorithm to track the static and dynamic boundary. In this work we are assuming that velocity of the dynamic boundary is less than the agent's velocity.

We consider 24-agent system, where 12 are actual agents and 12-are virtual agents. Figure 6 presents the evolution of the dynamic boundary. From figure 7, it is observed that the agents are converging to the boundary.

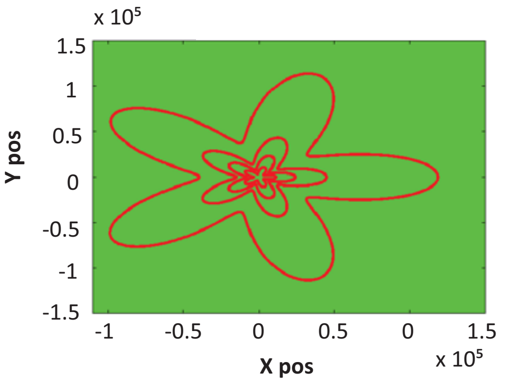

Figure 6: Temporal Evolution of the boundary

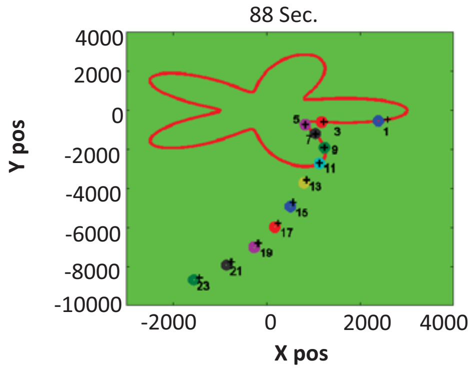

Figure 7: Convergence of the agents to the boundary

Open-house on UAV Technology

A unique open house demonstration of UAV technology was held on 27th March, 2015 at the Flight laboratory, IIT Kanpur. Working models of flapping wing bird, fixed wing unmanned aerial system and quadrotor were displayed during the demonstration. The progress of the projects was reviewed and appreciated by the subject experts.

Feedback/Suggestions

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