

An Indian-Australian research partnership

Project Title: **Coordination and Control of Unmanned Aerial and Ground Vehicle (UAV / UGV) Groups**

Project Number **IMURA0362**

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Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?

(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

Advanced computational engineering, simulation and manufacture

The research problem

Design, fabrication and control of Unmanned Aerial and Ground Vehicles (UAVs and UGVs) have become popular research topics during the last decade. Apart from various laboratories around the world, these vehicles have now been used in various military and civilian applications including surveillance, reconnaissance, search and rescue, and remote warfare. However, even today, all these operations require intensive human supervision and fully autonomous operation is still an interesting but challenging research problem. The situation becomes even more complicated when groups of UAV/UGVs are involved since computation, sensing, and communication are distributed over multiple agents and coordinating them to implement desirable collective behaviours is extremely difficult in general. Despite the difficulty, coordination and control of multiple UAVs and UGVs have many applications including automated highway systems, formation flight control, satellite clustering, mapping of unknown or partially known environments, and distributed manipulation. Given the numerous utilities of such coordinated UAV/UGV teams, effective design and control of such groups is an area of intense current research. This project aims to investigate this challenging problem by developing and implementing algorithms for autonomous coordination and control of multiple UAV/UGV teams.

The development of new theories for multi-agent coordination would require multiple tools from sophisticated mathematics. This project will primarily use techniques from algebraic geometry, algebraic graph theory and optimization theory for this purpose.

In addition to the associated theory, a testing facility consisting of multiple UAVs and UGVs will be developed as part



Figure 1: Quadcopter Prototype developed at IITB

of this project. After testing various prototype vehicles, the research group at IIT Bombay, has developed a fully programmable quadcopter model (see Figure 1) as the primary model to be used in the multi-UAV testbed. Similarly, the Monash University researchers have developed micro helicopter UAVs (Figure 2). This project will integrate these (and possibly more) vehicles into a team of completely autonomous groups capable of cooperative operations. Such operations include, but not limited to, formation flying, multi-agent surveillance, search and rescue, group pursuit and evasion. Each UAV will have a suite of inertial sensors for low-level stabilisation, and a camera-based motion capture system will be used to provide realtime position information to UAV/UGV teams. Onboard IEEE 802.15.4 compatible wireless transceivers will provide communication between vehicles and the base station as well as direct inter-vehicle communication.

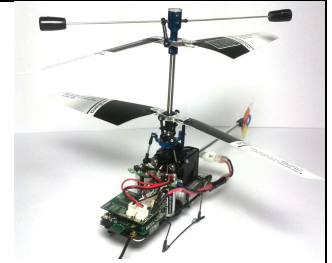


Figure 2: MAV testbed developed at Monash

Project aims

This project aims to develop and implement effective coordination and control algorithms for multiple UAV/UGV teams, which should then be able to accomplish autonomously various collective tasks such as formation flying, multi-agent surveillance, search and rescue, group pursuit and evasion etc. The developed algorithms will be tested on a multi-UAV/UGV testing facility, which will also be developed as part of this project.

Expected outcomes

The project will produce:

1. Various practically implementable and tested algorithms for cooperative control of multi-agent systems.
2. A complete electronic flight control system (including embedded autopilots, navigation tools, communication systems and their interfaces) for quadcopters and micro-helicopters.
3. A fully functional multiple UAV/UGV testing facility at IIT Bombay.

How will the project address the Goals of the above Themes?

The research on algorithms for UAV/UGV teams will investigate distributed formulations of optimal control problems in a feedback form. Developed algorithms will guarantee various properties (e.g. time optimality, maximal coverage, collision avoidance, etc.) by using only locally exchanged information. Combined with the multi-UGV/UAV testbed our project will provide experimentally validated distributed algorithms.

Capabilities and Degrees Required

Applications are invited from students with Bachelor's/Master's degree in electrical/electronic engineering, mechanical engineering, aerospace engineering, system and control, mathematics or physics. One student is required in each of the focus areas listed below:

1. Theory Focus: The applicant should be interested in systems and control theory, with a strong background in basic mathematics. He should have some understanding of linear control systems, linear algebra, differential equations and fundamentals of optimization. Some interest/knowledge in graph theory and combinatorics would be considered an advantage.
2. Application Focus: The candidate should have strong interest in mechatronics and robotics. He should be experienced in some of the following topics: embedded programming (e.g. Arduino, ARM, MSP430, etc.), circuit design, networking and data interface. Strong background in programming languages (C/C++) is preferred.