MiniDrone

A Miniature Drone for Swarm Robotics

ELECOMP Capstone Design Project 2020-2021

Sponsoring Entity:

Intelligent Control & Robotics Lab. (ICRL)
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Entity Overview:

For more than 50 years, robots have been confined to manufacturing facilities and other specialized application fields. But robotics technology is getting ready for widespread adoption and integration in the human society. New applications of mobile robots, both for professional use and for the general public, are being invented at an increasing pace. At the same time, new challenges arise when robots break free from the known controlled environment of factories to move into the real wide world.

The Intelligent Control and Robotics (ICRobots) laboratory at the University of Rhode Island is a world class research lab specializing in mobile and aerial robotics and multi-robot systems. Our vision is to bring cutting-edge robotic technology to application and consumers, to contribute to a better future.

The ICRobots lab includes three directing faculty members, from 2 different departments, six graduate students and several undergraduate students, with almost $2M in research funding from many state and federal agencies.

Technical Directors:

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Project Motivation:

Robotic swarms have the potential of widespread application including search and rescue operations, exploration, information gathering and clean-up of toxic spills, target search and tracking, and even construction. Swarms consist of a multitude of small inexpensive autonomous robots with limited capabilities. However, by collaborating with each other, they can perform complex tasks that they would not be able to perform alone.

The ICRobots lab is already very active in the development of fundamental theories and novel applications of robotic swarms. Our current setup includes several small wheeled robots equipped with cameras and 2D lidar sensors. We aim at complementing this facility with Mini Aerial Vehicles (MAV) that will bring our research activity to another elevated dimension.

The integration of different robotic platforms will allow for the development of heterogeneous algorithms that will exploit the diverse capabilities of the robots. For example, ground vehicles will have an operative role, moving objects and collecting on-site data, while MAVs will supervise the execution of the tasks and collect data with broader valence. The final setup will allow the ICRobots lab to expand its aim and impact on global research on robotic swarms.

Anticipated Best Outcome:

The Anticipated Best Outcome (ABO) of this project is a fully functional prototype of a single MAV that can be replicated to create a swarm. The MAV must be able to fly in the ICRobots lab testing area and tracked through the external motion capture system of the laboratory, following predetermined trajectories or commands of an operator. The MAV should have a maximum size of approximately 30 cm, with an expected weight of less or about 0.6 kg, and guarantee a flight time in hovering of 10 minutes or more. MAV's equipment should include a single-board Linux computer (SBC), a flight controller (FC), standard sensor equipment as an Inertial Measurement Unit (IMU), a barometer, and a single downward facing wide-angle camera.

The firmware for the FC and the software on the SBC should be developed starting from existing opensource projects as Paparazzi or Betaflight. The MAV should be interfaced through a wireless channel (wifi or dedicated wireless link as XBee) to a fixed base station running Ubuntu Linux, to provide flight data and sensor readings, and to accept external commands and communications from other robots in the swarm. The interfacing must be compatible with the Robot Operating System (ROS) development suit.

Additional features that go beyond ABO would be:

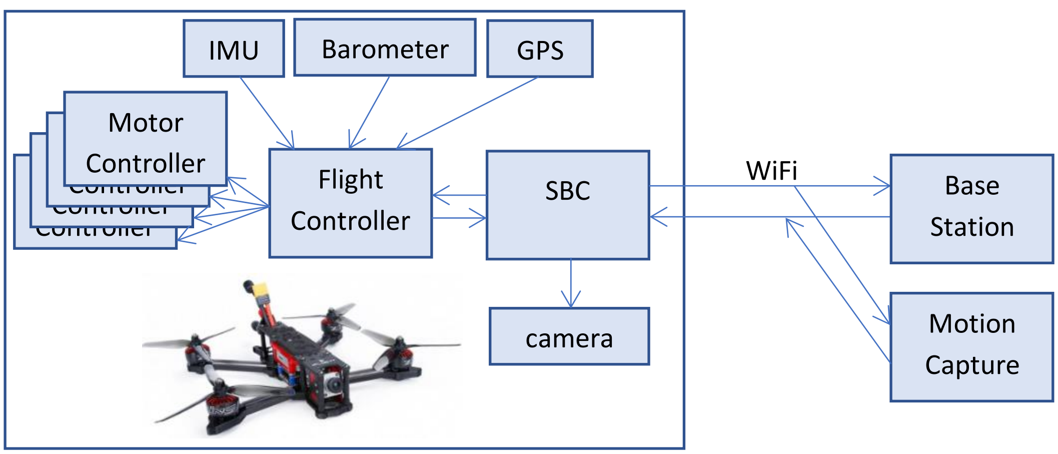
- Integration of additional sensors as GPS and sonars (for outdoor flight and automatic obstacle avoidance)
- Implementation of an MAV simulator in ROS/Gazebo
- Simultaneous flight of two or more MAVs

Project Details:

The hardware design of the drone is ***NOT*** the main challenge of this project. While it is important to properly select components and assemble them, the drone market is already mature enough to provide a vast choice of electronics and functional units, such as FCs, motor controllers, motors, sensors, and SBCs that are suitable for the proposed project. Similarly, the supporting structures as the main body and the arms can be selected among many available choices on the market. Moreover, there are examples online of similar MAVs already used in research (see for example https://wiki.paparazziuav.org/wiki/Main_Page). The selected FC will have an embedded IMU and barometer, or these sensors will need to be purchased separately and integrated on the final product. Moreover, a downward pointing wide-angle camera (ideally 180 deg horizontal field) will be integrated with the system and the collected images should be made available in real time to the SBC and potentially to the ground base. The fabrication of the MAV will also include wiring the components, while the structure could make use of custom-made 3D printed components. It is expected the hardware design of the drone to be finalized by the end of the Fall semester.

The main challenge of the project will be the *software integration of the different components* and the management of the information flow on the network. The flight controller should host an opensource autopilot as Paparazzi or Betaflight. Moreover, the autopilot software should be extended with novel modules according to the need to interface with additional sensors as sonars and GPS. The onboard SBC unit will host a Linux OS that will interface with the FC. The software in the SBC will rely on the ROS development suit and its libraries. Similarly, the software on the Linux ground control station will rely on ROS to send and receive data to the SBC via WiFi. Finally, always relying on ROS, the UAV will receive its position and orientation in the flying arena from an Optitrack motion capture system.

The level of integration that we are looking for is an MAV that can readily fly in our flying netted space, exchange data with a base station (including images collected with the onboard camera), and follow commands provided by an operator through a joypad connected to the base station.



The Product:
If the ABO is achieved the team will have created an MAV that can:

- Fit in a 40cm x 40cm box
- Fly in the ICRobots flying arena for 10 or more minutes in hovering
- Be commanded with a joypad from a base station
- Send telemetry data, sensor readings, and images to the base station through wifi

Hardware/Electrical Tasks:

- Selecting individual electronic components and structural units
- Determine layout and wiring for boards, sensor, etc., keeping in mind the need for a balanced distribution of weights
- Design and manufacture additional components for structural support and electronics as needed
- Determine inertial properties of the implemented MAV as weight, inertia matrix, and propeller parameters (lift/drag coefficients)

Firmware/Software/Computer Tasks:

- Firmware for the FC will be written in C or C++
    - Select and learn existing opensource autopilot code
    - Customize with additional modules as needed
    - Modular code will be essential
- ROS-based software for the SBC will be written in C++
    - Implement one or more ROS packages in Linux OS to interface with the FC and the base station
    - Modular code will be essential
    - Reuse existing opensource libraries as much as possible
- ROS-based software for the base station will be written in C++ and/or Python
    - Implement one or more ROS packages to interface the base station with the SBC with a simple client that will provide commands for the robot
    - Read commands from a joypad and send them through the connection to the SBC
    - Reuse available opensource ROS packages as much as possible

Joint Tasks:

- The organization of the software and its integration with ROS will require great concert effort. All team members should familiarize themselves with:
    - GNU/Linux OS and in particular Ubuntu (a great place to start is here https://www.theconstructsim.com/robotigniteacademy_learnros/ros-courses-library/linux-for-robotics/)
    - ROS with Python https://www.theconstructsim.com/robotigniteacademy_learnros/ros-courses-library/python-robotics/
    - ROS with C++ https://www.theconstructsim.com/robotigniteacademy_learnros/ros-courses-library/ros-courses-ros-basics-in-5-days-c/
- Select an opensource autopilot to serve as base for development

- Paparazzi and Betaflight are two popular choices – evaluate pros and cons, including possible existing ROS resources
    - The choice of the autopilot will limit the choice of compatible FC
- Select an SBC small enough for integration on the drone
    - Find a tradeoff between computational power, weight, size, power consumption, and overall features as number and type of supported interface ports
    - It is expected that a Linux OS will run on the SBC
- Testing: later on in the project the drone will need to be tested in the facility of the ICRobots Lab
    - Familiarize with motion capture system
    - Learn safe MAV testing practice

Composition of the Team:

2 Electrical (ELE) Engineers & 1 Computer (CPE) Engineer (preference will be given to 1 ELE, who can double-up as a CPE, as it has been clearly stated that "The main challenge of the project will be the *software integration of the different components."*

Skills Required:

Electrical Engineering Skills Required:

- Embedded programming
- Familiarity with computer architecture
- Experience with fast prototyping
- Familiarity with robotics or concurrent enrollment in ELE456 is a plus

Computer Engineering Skills Required:

- C/C++
- Familiarity with software architecture and organization
- Experience with opensource software
- Experience with complex systems is a plus

Anticipated Best Outcome's Impact on Entity's Business, and Economic Impact

This will be the first implementation of an MAV in the ICRobots lab and is meant to complement our robotic swarm of ground vehicles. Personnel in the laboratory will be excited to be able to work with aerial multi-robot systems on a daily basis. Leveraging on the different capabilities of this new platform with respect to our current robots, the laboratory will be able to extend their research activity to develop and propose novel heterogeneous algorithms and applications of swarm robotics, thus growing in its contribution towards robotics knowledge, and increasing the national and international reputation of the laboratory in the scientific community. With higher reputation and a novel platform to test with, the laboratory will be able to attract more funding from federal and state agencies.

Broader Implications of the Best Outcome on the Robotics Industry:

A successful outcome of this project will help the ICRobots laboratory to grow in size and improve the quality, quantity and variety of its work. On the one hand, an increase in research funding means will allow the lab to expand its organic and offering more graduate and undergraduate research assistantship.

On the other hand, the laboratory is always engaging the general public with demonstrations and participating in social events with the purpose of showing the potential of robotics to enhance and assist human society, with a particular focus on the younger generations. The developed platform will be a great showcase to familiarize people with robotics and attract students to the URI's ELECOMP Capstone Design Program.