Collaborative Research Project for CS and Engineering Students

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***Abstract*— This poster paper describes a multi-disciplinary and multi-year research project that involves students from Computer Science (CS), Aerospace Engineering (ARO), Electrical and Computer Engineering (ECE) and Mechanical Engineering (ME). They work as a team on solving the research problem of collaboration between Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs).** [1]

I. The Project

The problem that we are interested in is the collaboration between UAVs and UGVs to accomplish search and rescue tasks. Figure 1 describes one of the task scenario, where one UAV is flying in patterns to search a particular area for a potential object of interest. Once the geo-location of the target is found, it is transmitted over the network to the other two UAVs, which will fly near the target and drop water bottles to that location for rescue purposes. To make sure that multiple UAVs can fly at the same time, UAVS are programmed with the collision avoidance capabilities. Meanwhile, a UGV is set to navigate to the target location and verify the delivery. This project is naturally a multi-disciplinary project which requires the knowledge from ARO students for flight control, ECE students for the hardware design, ME students for mechanics, and CS students for software control.

This project has been sponsored by the Northrop Grumman Corporation (NGC) since 2011. The Pomona team also collaborated with the Cal Poly Slo team to divide and conquer the task. To demonstrate our project progress, we perform a yearly midterm design review to NGC and a final demonstration of the integrated system to NGC and the public every year. We are currently in year three of the project. This poster paper mainly describes the research project done in the Pomona team for the current year.

II. The Approach

A. Key Research Issues

1) UAV Collision Avoidance: The key operations required by our UAV includes: autonomous waypoint navigation, collision avoidance, autonomous payload release (water bottle), and manual override and failsafe (if needed). Our focus this year handles collision avoidance. We first perform simulation experiments to prove the avoidance capability. The mass properties of both UAVs are modeled and provided to the simulation team. The collision avoidance is essentially a detect-sense-avoid process. During the flight, UAVs will communicate their status such as position and velocity. Due to the unreliable GPS data, a kalman filter is used to approximate the UAV's position. When there's a potential collision, waypoints will be generated to steer UAV away from the collision course.

[1]This paper is submitted as a poster.

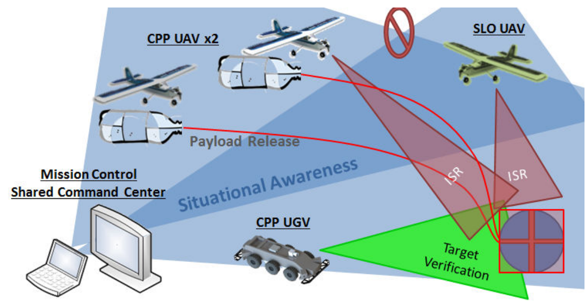

Fig. 1. Our task scenario with three UAVs and one UGV.

2) UGV Navigation: The tasks of the UGV include autonomous target search and recognition, retreat to safe zone, and return to verify the package delivery on target. The UGV uses a FPGA interface for motor control, sensor data acquisition (GPS, IMU, Sonars), and power control. There's an onboard processor to handle camera and lidar data and control the behavior layer. To achieve the prescribed tasks, the UGV is programmed with the following capabilities: 1) target recognition using OpenCV2. The primary target's position is calculated using current robot's state; 2) path planning using D* Lite [1]; and 3) waypoint navigation, including obstacle avoidance.

3) Ground Control Station (GCS): The GCS provides a graphical user interface for the human operator to oversee the team operation and intervene at critical time. Our goal is to maximize situation awareness and minimize the cognitive load of the operator. Through trade studies, we selected the following tools: the Qt framework, which provides user interface and database access; the ArcGIS, a geographical information system software which has the ability to show the map, add overlays, and allows users to interact with the map (zooming and panning); SQLite database; and our own Protonet communication protocol.

4) Communication: In our system, the UAVs need to communicate directly with each other for collision avoidance data. UAVs and UGVs also send their status back to the GCS. GCS may send command and control to the vehicles. We

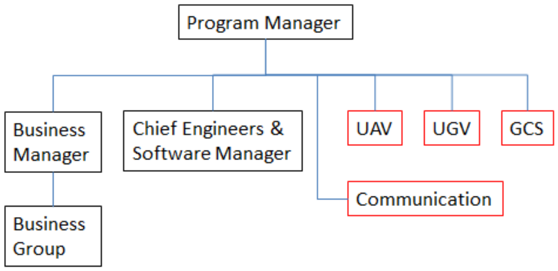

Fig. 2. Our team organization.

designed and developed our own Protonet protocol, which is a lightweight protocol that supports multiple platforms and languages. This is important because we have a large team with different expertise and we do not want to limit to one system and one language for software development.

B. Team Management

We have actively recruited students from CS, ARO, ECE and ME to work together in a large team. Each department also has one advisor to guide the research. Our student participation has increased significantly from 25 students in the first year, to 50 and 75 in the subsequent years. With such a large group of students, we need to have a management plan for the group to work efficiently towards the goal. We adopted a hierarchical management structure. The student body is led by a program manager with a support group of business majors for handling daily team operations, budget, logistics, and recruitment. Technically, the group is further divided into a group of chief engineers and software manager who have more expertise of the overall system, and a group for each key research area including UAV, UGV, GCS and communication. Each group is appointed a team lead and a business major to organize the research and operation within the group. Figure 2 gives an overview of our organization.

This year, our student body is mainly composed of undergraduate students and with 9 percent of graduate students. We also recognize that we need to have seats for Freshman or Sophomore students, since the seniors will graduate at the end of the year. We emphasize on mentoring and training of young students, encouraging young leaders, and promoting women in technical and leadership positions. As you can see from Figure 3, we have about 21 percent of returning members this year. Most of them are serving as mentors and leadership roles. The percentage of women participants also increased from 8 percent in the first year to 14 percent and 23 percent in the second and third year.

III. Results

A. Technical Results

Over the years, we have already successfully demonstrated our integrated system. In year one, our Pomona team mainly focused on the design and control of the UGV. We have successfully built our own UGV with on board computing, laser range finder, camera, IMU, sonars and FPGAs for sensor processing. The UGV has carried out the mission of

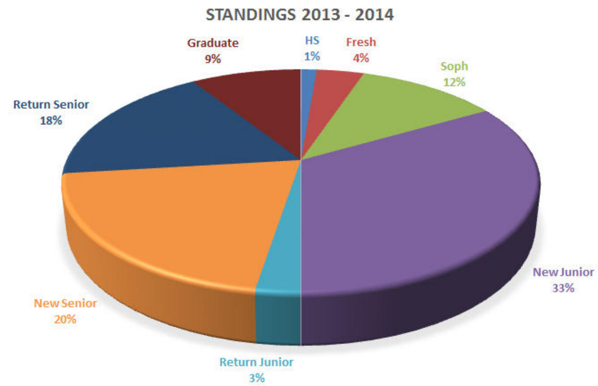

Fig. 3. Our current standings for 2013-14.

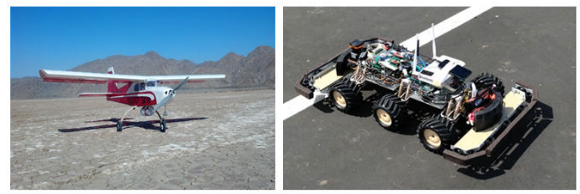

Fig. 4. The Sig Kadet (left) and the UGV (right).

waypoints navigation and obstacle avoidance. In year two, our team focused on developing the dropping mechanics and the dropping algorithm on a Sig Kadet airframe. We also optimized our hardware design for the UGV and added functionality such as target recognition. In our year-end demonstration, the UAV had an autonomous flight control and successfully dropped the water bottle near the target location. This year, we will demonstrate the more challenging UAV collision avoidance behavior in May 2014.

B. Other Benefits

Through a year's training, students from different departments get to work together as a team on a real-world application, which helps them to be a good team player, and to learn things that are not directly taught in the classroom. They all go through the whole process of design, development, and delivery of the product. Students gained more experience on their presentation skills and problem solving skills. The CS students have the opportunity to learn more on hardware and the engineering students can learn more about software. Many students evolved as team leads. Students also build their industrial connections with NGC. Several of our students got internship and full-time offers at NGC after their completion of the project.

IV. Conclusion

As a conclusion, this multi-disciplinary project has prepared the students with more hands-on experience, which is good for their future career development.

References

[1] S. Koenig and M. Likhachev. Fast replanning for navigation in unknown terrain. *IEEE Transactions on Robotics and Automation*, 2005.