SMALL UMANNED AERIAL VEHICLES IN TEACHING GEOSPATIAL DISCIPLINES

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ABSTRACT

The latest developments in small unmanned air vehicle (SUAV) technology make it possible to utilize SUAV platforms in geospatial disciplines research and teaching processes. Michigan Technological University is implementing a number of remotely controlled aircraft platforms in its photogrammetry course. The Surveying Engineering Program is working on a SUAV suite configuration that will make the following hands-on labs possible: project planning and potential accuracy analysis, implementation of project waypoints into the SUAV operational control unit, auto-pilot flight control over calibration sites and test-objects, and processing of gathered UAV imagery on softcopy photogrammetric workstations. The initial SUAV is equipped with autopilot and can carry up from 1 to 11 pounds of payload, and is currently fitted with a 7.1MP non-metric camera. Students use surveying grade GPS equipment to prepare calibration sites. Work on processing of the obtained datasets encompasses: bundle block adjustment, image co-registration, mosaicking, and finally feature extraction from UAV imagery. Comparison of the results obtained from the SUAV to respective results obtained from traditional aerial photogrammetry will provide an excellent opportunity for research investigation directed at accuracy and applicability of SUAV imagery for specific projects. Practical hands-on experience with SUAV control and imagery provides students a unique opportunity to participate in ongoing development and research activities in the geospatial science and industry.

INTRODUCTION

At present, there are numerous choices for low-cost SUAV aerial surveying platforms. Michigan Tech University is working with an adaptation of the Bio Robots LLC [1] 34 inch wingspan electric radio controlled airplane. The plane is equipped with an 8.5MP camera and Procerus Technologies[2] autopilot system. This very small SUAV was not sufficiently stable in flight tests at Michigan Tech, and it was therefore decided to perform further trials with different platforms. An alternate aircraft was built in the spring of 2007 for an SAE Aero Design competition. It was designed specifically for carrying the maximum weight possible given the following requirements: 0.61 cubic inch O.S. engine, 1000 square inch or less wing area, a payload bay of dimensions 16x4x4 inches, and capable of takeoff within 200 feet. The aircraft preformed several successful flights at the SAE Aero Design West competition in Van Nuys, California in March of 2007. It has since been outfitted with gear to carry and utilize a Panasonic Lumix 7.2 MP camera.

In addition, Michigan Tech is conducting research and development of a glider platform for aerial mapping purposes. This platform would provide very stable imagery due to the absence of vibrations during the image acquisition process. The glider may use a balloon to reach the designated altitude and then detach for glide/loiter flight. The launching methodology described above can potentially bring a glider to heights of 26,000 feet. With this capability image results could be applied to remote sensing teaching and research. This glider platform can carry up to 31 pounds payload. This paper will next describe past performed efforts in more detail.

SUAV PLATFORMS

Bio-Robots SUAV

Figure 1. a) Electric SUAV before launching. b) Camera bed of the electric SUAV plane.

The Bio-Robots SUAV platform has following characteristics:

- Weight ~850 grams (~30 oz)
- Wing Span = 34 inches, Length = 26 inches
- Airspeed ~12 m/s (~26 mph)
- Range ~3 km
- Primary payload – Canon Powershot SD1000
    - 7.1 Megapixels – 3,072 x 2,304 image
    - Continuous shooting at approximately 1.7 fps
    - 640 x 480 video @ 15 fps
- Operational Limitations – maximum 10 mph winds

The structure of this SUAV encompasses: Fuselage, Multi-segmented Main Wing, Tail Section – Horizontal Stabilizer, Vertical Stabilizers, Elevator, Rudders, Control Servos and Servo Arms, Control Rods and Control Horns, Landing Gear. SUAV is integrated with autopilot which is described in a later section of the current paper.

Michigan Tech SAE Aero Platform

This alternative SUAV was designed and tested by Michigan Tech Mechanical Engineering students and is depicted in Figure 2. The aircraft utilizes a unique high lift airfoil (Selig 1223) specifically designed for the competition the aircraft performed in. Because the airfoil generates a relatively large amount of lift it also generates a lot of drag. The result is that the aircraft flies relatively slowly (about 20-30 mph) depending on the payload weight. At the competition the aircraft flew successfully with approximately 20 pounds of steel in the payload section. The aircraft's empty weight is about 10-11 pounds.

The aircraft utilizes a carbon fiber fuselage with several bulkheads throughout. The wings are made of highly durable and lightweight foam with a balsawood coating. The wings are connected by a carbon fiber tube, which allows for reasonably quick and easy disassembly.

Figure 2. Michigan Tech SAE Aero gas driven SUAV and camera integration bed.

Michigan Tech SAE Aero aircraft has the following characteristics:

- Engine: O.S. .61 cubic inch 2-stroke
- Fuselage Length: 68.5 inches
- Wing Span: 78.5 inches
- Approximate Airspeed: 20-30 mph (dependent on overall weight)
- Flight Time: 10-15 minutes
- Payload Bay: 16x4.5x4.5 inches
- Empty weight 10-11 lb.
- Max Payload: ~20 lb.

Ongoing integration of the Procerus Kestrel autopilot is described in the following section.

SUAV FLIGHT CONTROL

Each of the possible SUAVs can be controlled in 2 modes: manual radio control (RC) or by means of an autopilot system (AUTO). Auto-pilot control is practical for the teaching process since the manual RC mode requires extensive pilot training and would increase the risk of damaging the high value SUAV platforms. Therefore, on-board autopilot hardware is crucial for the successful use of SUAV in classes. This autopilot is depicted on Figure 3.

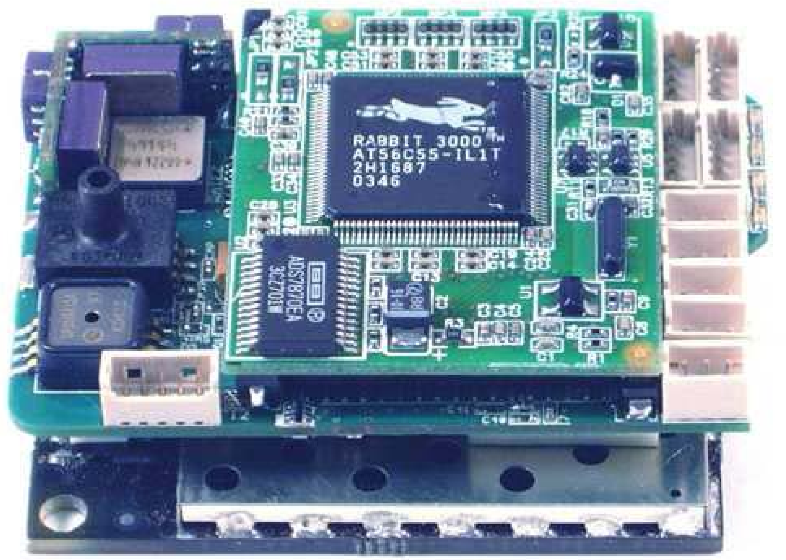

Figure 3. Kestrel autopilot onboard hardware.

This board encompasses:

- Main Board
  - Rate Gyros
  - Serial Ports
  - Servo Ports
  - Pressure Transducers
- Pitot Tube
- GPS Antenna
- 900 Mhz Modem
- Communications Antenna

Auto-pilot is operational by means of ground station components which include:

- Commbox
- Laptop
- RC Transmitter/Cable
- GamePad Controller
- Virtual Cockpit Interface

SUAV FLIGHT PREPARATION AND PERFORMANCE

Typical operational workflow to perform aerial image acquisition flight includes the following steps:

I. Vehicle pre-checking:

- Confirm all Assembly Fasteners are Securely Attached
- Inspect Control Horns, Control Rods, and Servo Arms for Damage/Attachment
- Ensure Propeller Securely Fastened
- Ensure Prop Adapter not Rubbing Boltheads
- Ensure Landing Gear Firmly Mounted
- Check that Servo Extension/Adapter Wires are Firmly Attached to Servo Wires
- Ensure GPS Antenna Securely Attached

II. Final launch preparations:

- Insert Camera
- Attach Camera Door
- Attach Camera Actuator to Camera
- Plug-in and Insert Battery
- Attach Battery Door
- Perform Procerus Pre-Flight Process
- Turn On Camera
- Adjust Camera Function Setting to Continuous Capture
- (Actuate Camera)
- Fasten Canopy Door
- Launch

Procerus autopilot allows execution of the following flight control operations after the launch: Real-time Display of Flight Track, Change Flight Plan Mid Flight, Waypoint Triggered Servo Feature, and Data Logging.

TEST-OBJECT AND EXPERIMENTS DESCRIPTION

The phtogrammetry lab students designed a test-object flight on the Michigan Tech campus. To develop this test-object flight, students made photogrammetric target "donuts" from cardboard. (See Figure 4).

Figure 4. Photogrammetric target ("donut") is installed on the ground.

The test–object design included 18 targets placed on the ground according to the scheme presented on Figure 5. Nine targets were placed within the projected footprint of a single image for calibration purposes, and the rest of targets were equally distributed over the projected flight strip.

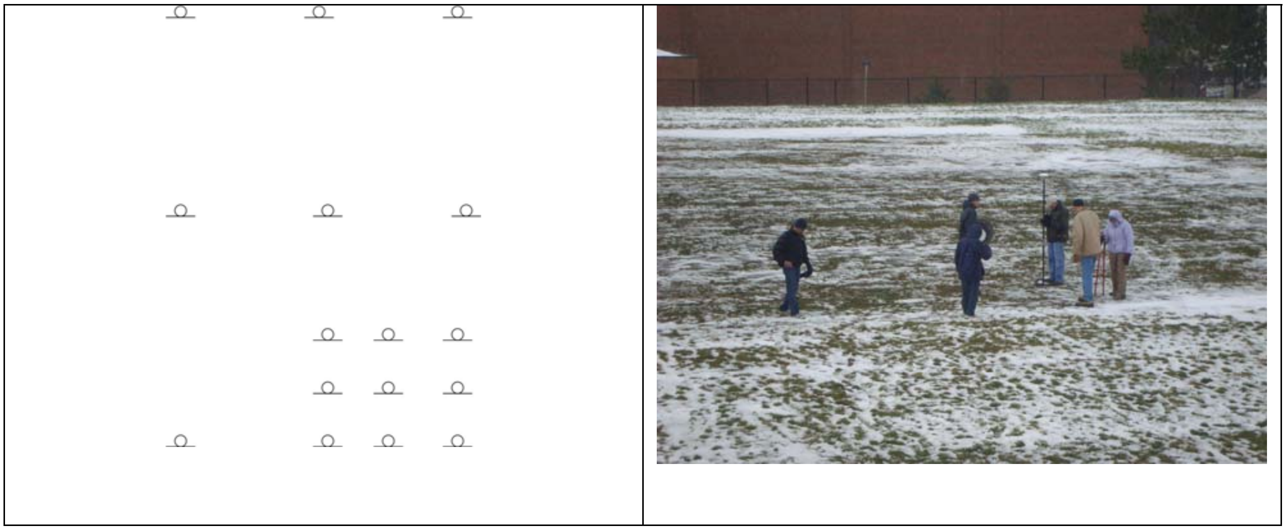

Figure 5. a.)Targets distribution over test-objects. b) Surveying engineering students coordinating targets using GPS RTK system.

Each target was surveyed with a Trimble R8 GNSS system utilizing real-time kinematic (RTK) technology with positional accuracy of 10 mm horizontal and 20 mm vertical. SUAV flight with image acquisition was then performed.

Figure 6. SUAV during mission.

Processing the results from the SUAV test-object flight is the final step. Cardinal Systems VrMapping system [3] and special applications written on Matlab are used. Results will be published when analysis is finished.

CONCLUSION AND OUTLOOK

Michigan Tech's SUAV lab combines for students both elements of excitement and practical application of photogrammetry practices. Specifically, flight planning and calibration are considered a hands-on experience during SUAV labs. Moreover, students are learning about different geospatial fields such as platform guidance navigation and control, robotics, and sensors. They will be able to use the skills and knowledge obtained from this lab for real-life scenarios.

FUTURE WORK

Future developments will be devoted to the finalization of the SUAV data obtaining processes by implementation within GIS and 3D visualization environments. Moreover, applying various spectral filters may develop a valuable potential for remote sensing studies. For instance, infrared filters may be used for wildfire detection and prevention, etc. Fusion of the UAV imagery with aerial and satellite data opens another opportunity for graduate and post-graduate research.

REFERENCES

Bio Robots LLC home page: http://bio-robots.com/forum/faq.php?faq=vb_faq
Procerus Technologies autopilot web page: http://www.procerusuav.com/
Vr Mapping web page: http://www.cardinalsystems.net/